1973

SOIL PLANT NUTRIENT RESEARCH REPORT

compiled by

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In soil fertility research, it is vital to conduct experiments under a wide variety of soil and climatic conditions. Almost all of the investigations were carried out on individual farms throughout the province. Without the generous co-operation of the many farmers involved, it would be impossible to conduct research of this type. A sincere thank-you is extended to all farmers who put up with considerable inconvenience to accommodate these experiments.

The project in the irrigation area is a co-operative project between the Department of Soil Science and the Conservation and Development Branch of the Saskatchewan Department of Agriculture. Ron Martin was a summer assistant with the project and with the assistance of Brian Lynch, took care of all moisture readings, water application and plot maintenance. Dwayne Climenhaga and Wayne Randall designed the sprinkler systems used on the water control experiments. Many other supervisory personnel and technical assistants helped with various aspects of the project.

Many of the research investigations conducted on the fababean project were performed by two overseas graduate students-in-training under the supervision of various staff members. Funding for the two visiting students, Dick Nwachuku and Takashi Muraoka, was arranged through the International Atomic Energy Agency and C.I.D.A.

The soil productivity study in the Swift Current map area is a joint project with the Canada Department of Agriculture Research Station at Swift Current. Personnel from that station aided in selection, harvested all forage plots and threshed and weighed the wheat samples and did the protein analyses.

All field operations including seeding, maintenance and harvesting of the field plots were carried out by summer assistants including Ron Martin, Laurie Tollefson, Pat Coffy, Paul Kneeshaw and Blake Maybank. Nitrogen, protein and oil analyses of plant material were performed by Denny Holben and Bob Ostafie of the Saskatchewan Soil Testing Laboratory. The laboratory also performed all routine soil analyses. Mass spectrometric analyses were performed by Lloyd Johns with assistance from Mervyn Manthey.

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1. NUTRIENT AND WATER REQUIREMENTS OF IRRIGATED CROPS

INTRODUCTION

In 1971 a research project was initiated in the Outlook area of the South Saskatchewan River Irrigation Project with the following objectives:

(1) to assess effects of nutrient levels (particularly of nitrogen) and irrigation scheduling on the yields and quality of a variety of crops including barley, soft wheat, rapeseed and alfalfa.

(2) to provide guidelines on the fertilizer and water requirements for optimum production of these crops under irrigation.

(3) to establish guidelines for target yield estimations.

To meet these objectives, a series of field experiments were conducted in 1971 and again in 1972. In 1973 a similar set of field fertility trials were established with the main objective being to obtain fertility response information to provide confirmation of the fairly consistent trends in yield response observed in the previous two years. This information has provided the basis for improved fertilizer recommendation guidelines presently being used by the Saskatchewan Soil Testing Laboratory.

Another important objective of the 1973 trials was to document the benefits of good irrigation practices. This was done by setting out an irrigation scheduling study in which crops were subjected to periods of planned moisture stress.

Also included in the 1973 program was a set of "demonstration" type trials which were established to investigate the response of irrigated corn to applied fertilizer nutrients.

1.1 Nutrient requirements of barley, soft wheat and rapeseed

EXPERIMENTAL METHODS

For the crops barley, soft wheat and rapeseed two types of nutrient response experiments were conducted. In the first series of experiments, referred to subsequently as the "water control" or "Type A" experiments complete control was maintained over both the amount of fertilizer nutrients applied as well as the amount and time of irrigation water applied. Type A experiments involved growing each of the crops under a variety of fertility treatments and under both a dryland and an optimum irrigation situation. An integral part of these experiments was an investigation dealing with plant moisture use, irrigation scheduling, and the effects of moisture stress on crop yield. Results of these aspects of the investigation are presented in subsequent sections of this report.

For the Type A experiments two sites were selected on stubble fields. One site was in an Asquith very fine sandy loam soil (Davison farm) and the second site was on an Elstow loam (Anderson farm). Characteristics of the experimental sites and the initial soil analyses results are presented in Tables 1.1.1 and 1.1.2. Small plots of the randomized complete block design were set out at both locations, containing for all three crops and for both the dryland and optimum irrigation situation, thirteen treatments replicated four times. The fertility treatments used in these experiments are listed in Table 1.1.3. The varieties of crops

Table 1.1.1 Characteristics of sites selected for 1973 irrigation experiments.

Crop	Variety	Farmer Cooperator	Previous Crop	Soil Association	Texture	Type of Irrigation
I. Water Control Experiments (Type A)						
Barley	Betzes	Anderson		Elstow	loam	sprinkler
Soft Wheat	Springfield					
Rapeseed	Midas					
Barley	Bonanza	Davison		Asquith	very fine sandy loam	sprinkler
Soft Wheat	Springfield					
Rapeseed	Midas					
II. Field Experiments (Type C)						
Barley	Conquest	Carlson	Oats	Elstow	loam	border dike
Barley	Betzes	Pederson	Potatoes	Elstow	loam	sprinkler
Barley	Bonanza	Stranden	Fababeans	Elstow	loam	border dike
Soft Wheat	Lemhi 62	Carlson	Barley	Elstow	loam	border dike
Soft Wheat	Springfield	Niska	Rapeseed	Bradwell	very fine sandy loam	sprinkler
Soft Wheat	Lemhi 62	Pederson	Potatoes	Elstow	loam	sprinkler
Rapeseed	Torch	Carlson		Bradwell	very fine sandy loam	sprinkler
Rapeseed		Niska	Soft Wheat	Elstow	loam	sprinkler
Rapeseed	Zephyr	Pederson	Flax	Elstow	loam	sprinkler

able 1.1.2 Results of analyses of soil from sites selected for 1973 irrigation experiments[1].

ooperator/ Crop	Soil type Texture	Depth inches	NO_3-N	$NaHCO_3$ Ext-P (lb/acre)	$NaHCO_3$ Ext-K	SO_4-S	pH	Cond. mmho/cm
) Water Control Experiments (Type A)								
nderson/	E:l	0-6	4	11	745	20	7.7	0.4
arley		6-12	5	3	280	11	7.9	0.4
oft Wheat		12-24	3	4	550	35	8.2	0.6
apeseed		24-36	3	14	805	52+	8.2	2.2
		36-48	3	21	1075	52+	7.7	5.3
avison/	A:vl	0-6	5	5	690	4	7.9	0.2
arley		6-12	5	1	270	5	7.9	0.3
oft Wheat		12-24	10	2	320	12	7.9	0.3
apeseed		24-36	5	2	395	15	8.1	0.3
		36-48	4	2	495	27	8.3	0.3
) Field Experiments (Type C)								
arlson/	E:l	0-6	7	13	670	13	7.6	0.3
arley		6-12	8	7	480	15	7.7	0.4
		12-24	19	4	560	35	7.9	0.5
ederson/	E:l	0-6	16	20	450	14	7.5	0.4
arley		6-12	13	5	255	15	7.7	0.5
		12-24	12	3	555	33	8.0	0.5
tranden/	E:l	0-6	6	4	635	6	7.1	0.3
arley		6-12	7	1	335	6	7.4	0.3
		12-24	12	2	500	23	7.7	0.3
arlson/	E:l	0-6	5	12	300	15	8.0	0.3
oft Wheat		6-12	5	2	200	17	8.1	0.3
		12-24	9	6	500	52+	8.3	0.5
iska/	Br:vl	0-6	26	23	570	17	7.3	0.4
oft Wheat		6-12	22	8	345	13	7.5	0.4
		12-24	43	5	465	37	7.7	0.4
ederson/	E:l	0-6	26	19	355	12	7.5	0.5
oft Wheat		6-12	12	6	210	12	7.8	0.4
		12-24	14	8	490	30	8.1	0.4
arlson/	Br:vl	0-6	19	21	745	26+	7.1	0.4
apeseed		6-12	10	4	350	18	7.4	0.4
		12-24	13	2	535	52+	7.6	1.3
iska/	E:l	0-6	16	24	520	12	7.3	0.3
apeseed		6-12	12	14	330	10	7.5	0.3
		12-24	12	6	370	26	7.8	0.4

Table 1.1.2 Con't.

Cooperator/ Crop	Soil type Texture	Depth inches	NO_3-N	$NaHCO_3$ Ext-P (lb/acre)	$NaHCO_3$ Ext-K (lb/acre)	SO_4-S	pH	Cond. mmho/cm
Pederson/ Rapeseed	E:1	0-6	7	23	495	9	7.7	0.4
		6-12	5	6	315	16	7.9	0.4
		12-24	10	9	580	46	8.1	0.5

[1]Based on samples taken prior to seeding.

Table 1.1.3 Fertility treatments used in irrigation experiments[1].

Treatment Number	Nutrients Applied (lb/acre)			
	N[2]	P_2O_5[3]	K_2O[4]	S
1	0	40	0	0
2	25	40	0	0
3	50	40	0	0
4	75	40	0	0
5	100	40	0	0
6	150	40	0	0
7	200	40	0	0
8	300	40	0	0
9	50+50	40	0	0
10	75+75	40	0	0
11	200	40+110	0	0
12	200	40+110	120	0
13	200	40+110	120	60
14	200	40+110	0	60

[1]Treatments 1 to 13 used in Water Control (Type A) experiments. Treatments 1 to 14 used in Field experiments (Type C).

[2]Rates of nitrogen are in addition to that supplied by the ammonium phosphate (11-55-0). Nitrogen in treatments 2 to 12 was applied as broadcast ammonium-nitrate while in treatments 13 and 14 as broadcast urea-ammonium sulphate (34-0-0 11% S). In treatments 9 and 10 half of the nitrogen was broadcast at seeding, and the remaining half broadcast in late June.

[3]Phosphate was applied in all cases as seed drilled ammonium phosphate (11-55-0). In the Water Control experiments phosphate was applied at a rate of 40 lb P_2O_5/acre to barley and soft wheat and at 30 lb P_2O_5/acre to rapeseed. In the Field experiments phosphate was applied by the cooperating farmer. Additional phosphate in treatments 11 to 14 was applied at seeding as broadcast ammonium phosphate.

[4]Potassium was applied in treatments 13 and 14 as broadcast potassium chloride (0-0-60).

seeded included Springfield soft wheat and Midas rapeseed at both sites and Bonanza and Betzes barley respectively at the Asquith and Elstow soil sites. All treatments received a blanket application of seed drilled ammonium phosphate (11-55-0) applied at a rate of 40 lb P_2O_5/acre for barley and soft wheat and at 30 lb P_2O_5/acre for rapeseed. Additional nitrogen was broadcast at seeding at rates up to 300 lb N/acre. In addition separate treatments were included where a portion of the nitrogen was broadcast at seeding time and the remainder was applied later in the growing season (late June). To augment the information on the split applications, additional treatments utilizing specially labelled ^{15}N fertilizers were set out. Other treatments included the broadcast application of additional phosphorus, potassium and sulphur.

Irrigation water was applied on the Type A plots through the use of a custom designed sprinkler system. Approximately one inch of water was applied to all plots (including the dryland plots) immediately after seeding to ensure germination. Subsequently, all of the optimum irrigation plots received water in amounts adequate to meet the crop requirements. (The method for determining time and amounts of water required will be discussed in a subsequent section.)

Avadex was used as a preplant application for the control of wild oats in the barley plots, and Treflan was applied preplant on rapeseed. Past emergent herbicides used for weed control included Buctril-M and 2,4-D amine on barley and wheat, and Tok-RM and TCA on rapeseed. No wild oat control was used in the wheat plots, however, wild oat occurrence was minimal. Malathion was applied to all rapeseed plots for the control of flea beetles, and was applied to all crops on the Anderson site to control the heavy grasshopper infestation which occurred in early July.

A second series of experiments referred to subsequently as "field" or "Type C" experiments was conducted in which control was maintained only over the amount of fertilizer nutrients applied. Three sites were selected for each of the three crops. Data on the site characteristics and initial soil analyses results are presented in Table 1.1.1 and 1.1.2.

Type C experimental plots were of the field scale randomized complete block design containing 14 treatments replicated six times. The treatments (Table 1.1.3) were similar to those of the Type A experiments. All pre-seeding tillage and seeding operations were conducted by the co-operating farmer and irrigation water was applied by the co-operating farmer when he felt the crop required it.

At harvest, samples were taken from all treatments of all the Type A and C plots, dried, threshed, and weighed. Subsamples of both grain and straw were taken (replicates of individual treatments from each plot were composited and mixed), ground, and analyses were performed for % nitrogen content of the straw, % protein content of the grain, and in the case of rapeseed, % oil content of the seed (unground).

RESULTS AND DISCUSSION

Response of barley to nitrogen fertilization

Data on the effect of nitrogen fertilization on the yield and nitrogen uptake of barley from the various plots are presented in Tables 1.1.4, 1.1.5 and 1.1.6. In most cases, good yield responses

Table 1.1.4 The effect of nitrogen fertilization on the yield, nitrogen content, and nitrogen uptake of Betzes barley grown on Elstow soil[1] (Anderson site).

N Applied lb/ac	Yield		Grain/ Straw ratio	Grain[2] % Prot.	Straw[3] % N	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac				Grain	Straw (lb/acre)	Total
			Optimum Irrigation					
0	32.0	1259	1.2125	8.62	0.35	22.7	4.4	27.1
25	46.2	2367	0.9450	8.57	0.36	32.6	8.5	41.1
50	65.7	3321	0.9550	8.57	0.41	46.4	13.6	60.0
75	55.4	2916	0.9125	8.57	0.33	39.1	9.6	48.7
100	54.5	2741	0.9550	8.87	0.41	39.8	11.2	51.0
150	69.2	3436	0.9800	9.88	0.45	56.3	15.5	71.8
200	68.9	3497	0.9400	11.44	0.56	64.9	19.6	84.5
300	74.7	4082	0.8875	13.76	0.70	84.6	28.6	113.2
			Dry Land					
0	20.5	947	1.0475	8.97	0.40	15.1	3.8	18.9
25	24.6	1254	0.9475	10.84	0.55	22.0	6.9	28.9
50	30.2	1469	0.9950	11.14	0.57	27.7	8.4	36.1
75	31.4	1459	1.0750	12.15	0.61	31.4	8.9	40.3
100	33.0	1722	0.9350	11.84	0.71	32.2	12.2	44.4
150	21.9	1725	0.7150	14.46	0.74	26.1	12.8	38.9
200	28.8	1579	0.8800	14.52	0.90	34.4	14.2	48.6
300	28.9	1262	1.1075	14.01	0.81	33.3	10.2	43.5

[1]Soil nitrogen content at seeding was 12 lb NO_3-N/acre to 2 feet.

[2]Grain protein content based on % N at 13.5% moisture x 5.83.

[3]Straw % N on oven dry basis.

Table 1.1.5 The effect of nitrogen fertilization on the yield, nitrogen content, and nitrogen uptake of Bonanza barley grown on Asquith soil[1] (Davison site).

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain[2] % Prot.	Straw[3] % N	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac				Grain	Straw (lb/acre)	Total
			Optimum Irrigation					
0	28.0	1119	1.2075	10.43	0.50	24.1	5.6	29.7
25	44.7	2051	1.0500	9.32	0.56	34.3	11.5	45.8
50	55.5	2388	1.1150	10.28	0.51	47.0	12.2	59.2
75	53.7	2487	1.0475	9.78	0.55	43.2	13.7	56.9
100	58.6	2702	1.0450	10.53	0.55	50.8	14.9	65.7
150	59.5	2609	1.0950	11.94	0.67	58.5	17.5	76.0
200	60.5	2786	1.0750	12.1	0.81	60.3	22.6	82.9
300	67.0	3698	0.9175	12.55	1.05	69.2	38.3	107.5
			Dry Land					
0	18.8	717	1.2525	9.17	0.61	14.2	4.4	18.6
25	38.7	1515	1.2250	10.08	0.45	32.1	6.8	38.9
50	48.4	2130	1.1050	10.53	0.55	42.0	11.7	53.7
75	43.1	1818	1.1650	11.79	0.57	41.8	10.4	52.2
100	42.1	1758	1.1525	11.84	0.71	41.0	12.5	53.5
150	49.2	2171	1.0925	13.31	0.80	53.9	17.4	71.3
200	49.3	2150	1.0225	14.06	0.95	52.4	20.4	72.8
300	43.9	1986	1.0625	13.86	1.18	50.1	23.4	73.5

[1] Soil nitrogen content at seeding was 20 lb NO_3-N/acre to 2 feet.

[2] Grain protein content based on % N at 13.5% moisture x 5.83.

[3] Straw % N on oven dry basis.

Table 1.1.6 The effect of nitrogen fertilization on the yield, nitrogen content, and nitrogen uptake of barley grown under irrigation on field experiments.

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain[1] % Prot.	Straw[2] % N	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac				Grain (lb/acre)	Straw (lb/acre)	Total (lb/acre)
	Carlson site[3] (Elstow soil) - Conquest barley (Soil NO_3-N at seeding = 34 lb/ac to 2 feet)							
0	78.4	3755	1.0117	12.95	0.46	83.6	17.3	100.9
25	70.1	3556	0.9617	12.95	0.60	74.7	21.3	96.0
50	83.4	3533	1.1533	11.44	0.88	78.6	31.1	109.7
75	86.8	3774	1.1183	13.71	0.90	98.0	34.0	132.0
100	80.3	3543	1.0900	13.46	1.09	89.0	38.6	127.6
150	81.1	3911	1.0067	12.9	1.06	86.1	41.5	127.6
200	90.0	3664	1.1917	13.71	1.05	101.6	38.5	140.1
300	94.2	4195	1.1100	13.86	1.24			
	Pederson site (Elstow soil) - Betzes barley (Soil NO_3-N at seeding = 41 lb/ac to 2 feet)							
0	65.2	3616	0.8783	11.09	0.43	59.5	15.6	75.1
25	64.0	3934	0.7900	12.1	0.51	63.8	20.1	83.9
50	60.2	3608	0.7950	12.7	0.78	63.0	28.1	91.1
75	59.5	3707	0.7650	13.66	0.78	66.9	28.9	95.8
100	56.4	4037	0.7017	13.71	0.91	63.7	36.7	100.4
150	69.4	4109	0.7433	13.91	0.96	72.6	39.5	112.1
200	68.1	4762	0.7383	14.01	0.90	78.6	47.9	121.5
300	64.6	5094	0.6300	14.36	1.16	76.4	59.1	135.5
	Stranden site (Elstow soil) - Bonanza barley (Soil NO_3-N at seeding = 25 lb/ac to 2 feet)							
0	19.6	1290	0.8967	9.27	0.39	15.0	5.0	20.0
25	34.4	2268	0.8383	9.42	0.37	26.7	8.4	35.1
50	36.9	2596	0.7917	8.47	0.31	35.7	8.1	33.8
75	51.1	2665	1.0017	9.32	0.37	39.2	9.9	49.1
100	56.2	3110	0.9950	8.62	0.41	39.9	12.8	52.7
150	62.0	3322	0.9900	10.94	0.54	59.9	17.9	73.8
200	62.1	3674	0.8967	10.79	0.46	55.2	16.9	72.1
300	74.3	4337	0.9067	13.31	1.20	81.4	52.0	133.4

[1]Grain protein content based on % N at 13.5% moisture x 5.83.

[2]Straw % N on oven dry basis.

[3]On the Carlson site, the entire plot received a blanket application of approximately 100 lb N/acre.

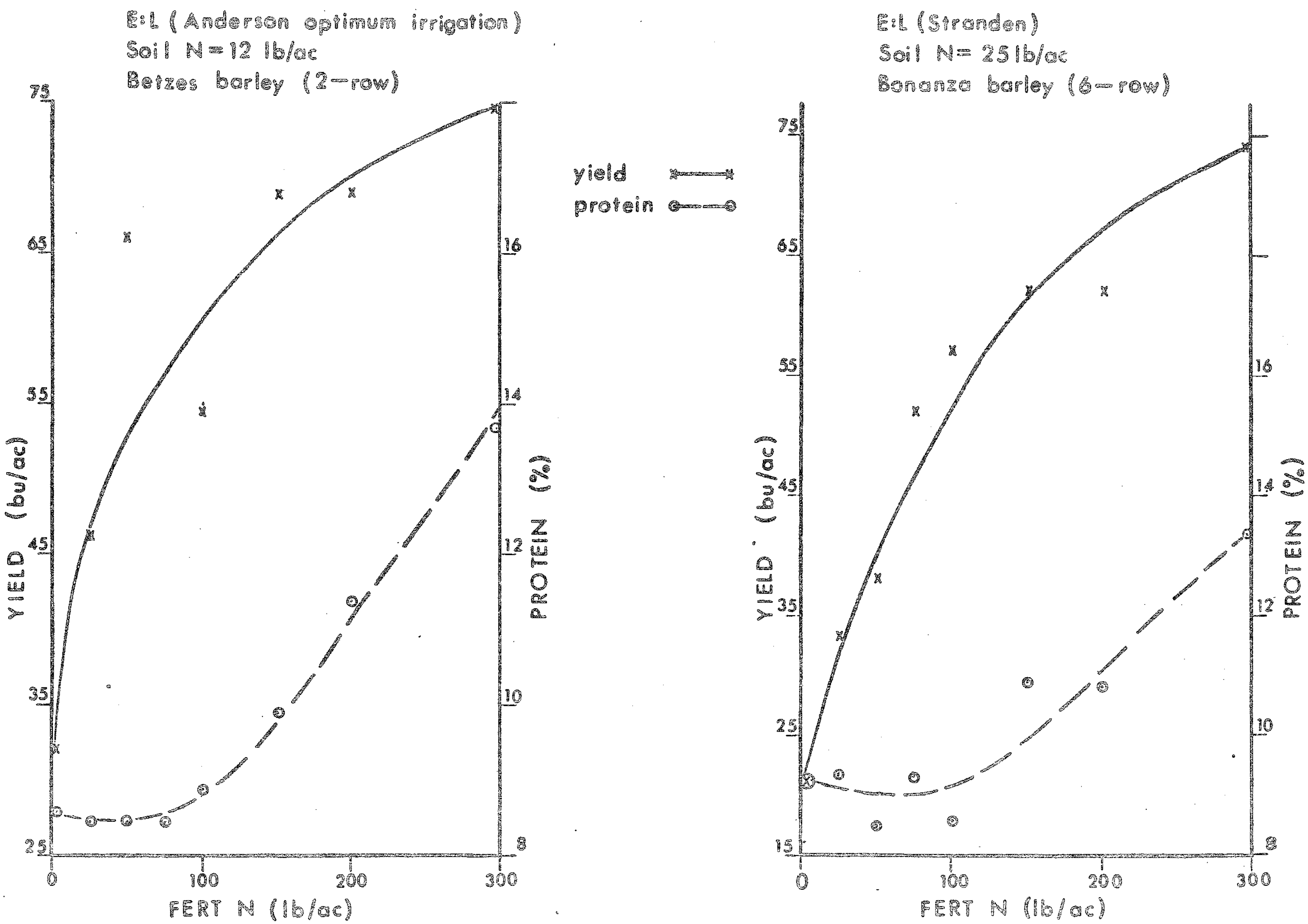

FIG.1.1.1 The effect of nitrogen fertilization on the yield and protein content of barley.

of barley to applied nitrogen were realized, with maximum yields under irrigation ranging from approximately 65 to 90 bu/acre at higher nitrogen application rates. All of the soils on which plots were located had an initial NO_3-N content in either the very low, low or medium category, and hence good responses would be expected. At the one site (Carlson site) where yields ranged from 70 to 95 bu/acre, the entire plot received an initial blanket application of approximately 100 lb N/acre which may, in part, explain the higher yields attained. One the one plot (Pederson site) where essentially no response was realized, the average barley yield was approximately 65 bu/acre. This site had the highest initial soil NO_3-N content (41 lbs NO_3-N/acre to 2 feet), and only received one irrigation in late June (1.91 inches of water) which may have resulted in the lack of response noted. All other barley plots received at least two irrigations.

Results from the two water control experiments clearly show the effect that adequate moisture has on the yields of barley. At both locations the plots receiving optimum irrigation far out yielded those grown under dryland conditions, particularly on the Asquith soil. Maximum yields of approximately 65 and 75 bu/acre were realized on optimum irrigation plots on the Asquith and Elstow soil sites, respectively, as opposed to maximum yield of approximately 50 and 30 bu/acre on the dryland plots at these same locations. On the optimum irrigation plots, barley continued to show response up to 300 lb applied N/acre while on the dryland plots maximum yields were achieved at approximately 100 to 150 lb applied N/acre.

Data from this years experiment, in contrast to that from previous years, indicated that two row varieties of barley can produce yields comparable to six row varieties.

The ratio of grain to straw production in this year's results does not show a consistent trend. In previous years there was a tendency for the ratio to decrease with increasing rates of nitrogen fertilization. This trend, which may be apparent in data from some of the plots would indicate that grain production does not increase as rapidly as total plant material with increase in nitrogen fertilization. The grain/straw ratio does, however, vary markedly from one trial location to another. It appears to be lowest on the site with the highest initial NO_3-N content (Pederson site). This site, however, received the lowest amount of irrigation water.

Grain protein and straw nitrogen contents generally increase with increased rates of applied nitrogen and marked increases occur at higher nitrogen application rates where yields tend to reach a maximum (around 200 lb applied N/acre). Highest overall protein contents of barley were realized at the Carlson site where all plots received an initial 100 lb N/acre. On the Pederson site where yields remained fairly constant at all levels of applied nitrogen, protein contents tended to increased with each increment of applied nitrogen. On the water control plots, the barley grown under dryland conditions contained higher protein levels than the barley grown under irrigation, since, presumably yields were limited by the amount of available moisture.

A direct result of increased yields and increased protein and nitrogen content of the plant material with increased rates of nitrogen is an overall increase in total nitrogen uptake by the crops at all locations.

Response of soft wheat to nitrogen fertilization

Tables 1.1.7, 1.1.8 and 1.1.9 present yield and nitrogen uptake results for the soft wheat plots. Maximum yields of irrigated soft wheat attained were in the neighborhood of 60 to 70 bu/acre. Good responses of soft wheat to applied nitrogen were realized at all but one plot site. At the Niska site, where initial soil NO_3-N levels were in the very high + category, a maximum of approximately 60 bu/acre was realized on the treatment which received no nitrogen. Increasing rates of applied nitrogen resulted in a decline in yield due primarily to lodging of the crop. On the two water control experimental sites and on the Carlson field scale experimental site where initial soil NO_3-N levels fell in the low and very low categories strong responses to applied nitrogen were realized with maximum yield in excess of 50 bu/acre being attained on two of the three sites at high nitrogen application rates. The reason why the soft wheat on the Davison site did not yield quite as well is not immediately apparent. On the Pederson site, where initial soil NO_3-N content was in the high category yields ranged from around 47 bu/acre on the check treatment to a maximum of approximately 69 bu/acre on the 150 lb applied N/acre treatment.

Similar results on the effect that adequate moisture has on yields were apparent in the soft wheat data for the water control plots as was evident in the barley data. Maximum yields of

Table 1.1.7 The effect of nitrogen fertilization on the yield, nitrogen content, and nitrogen uptake of Springfield soft wheat grown on Elstow soil[1] (Anderson site).

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain[2] % Prot.	Straw[3] % N	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac				Grain	Straw (lb/acre)	Total
			Optimum Irrigation					
0	18.0	1065	1.0175	8.79	0.32	17.9	3.4	21.3
25	32.8	2025	0.9650	9.17	0.33	33.1	6.7	39.8
50	38.8	2674	0.8900	8.74	0.36	38.3	9.6	47.9
75	42.5	2820	0.9175	9.2	0.36	44.1	10.2	54.3
100	46.4	2674	1.0525	9.52	0.43	49.8	11.5	61.3
150	45.3	2732	0.9975	10.58	0.52	54.1	14.2	68.3
200	52.3	3035	1.0400	11.5	0.57	67.8	17.3	85.1
300	48.3	3156	0.9275	11.96	0.69	65.2	21.8	87.0
			Dry Land					
0	11.1	975	0.6850	9.06	0.36	11.3	3.5	14.8
25	21.8	1747	0.7475	10.30	0.45	25.3	7.9	33.2
50	22.4	1787	0.7475	10.44	0.46	26.4	8.2	34.6
75	23.1	1715	0.8000	12.70	0.52	33.1	8.9	42.0
100	19.1	1554	0.7250	12.14	0.58	26.2	9.0	35.2
150	21.7	1836	0.6975	12.97	0.60	31.7	11.0	42.7
200	26.4	2061	0.7725	13.06	0.61	38.9	12.6	51.5
300	23.0	1976	0.6950	13.43	0.68	34.8	13.4	48.2

[1]Soil nitrogen content at seeding was 12 lb NO_3-N/acre to 2 feet.

[2]Grain protein content based on % N at 13.5% moisture x 5.32.

[3]Straw % N on oven dry basis.

Table 1.1.8 The effect of nitrogen fertilization on the yield, nitrogen content, and nitrogen uptake of Springfield soft wheat grown on Asquith soil[1] (Davison site).

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain[2] % Prot.	Straw[3] % N	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac				Grain	Straw (lb/acre)	Total
			Optimum Irrigation					
0	16.7	899	1.1125	8.65	0.36	16.3	3.2	19.5
25	33.2	1944	1.0225	8.51	0.29	31.9	5.6	37.5
50	37.0	2218	1.0025	8.92	0.46	37.2	10.2	47.4
75	36.6	2351	0.9300	9.71	0.43	40.1	10.1	50.2
100	38.4	2426	0.9600	10.4	0.43	45.0	10.4	55.4
150	42.0	2849	0.8900	11.13	0.57	52.7	16.2	68.9
200	43.7	2850	0.9200	12.05	0.64	59.4	18.2	77.6
300	37.1	2698	0.8200	12.97	0.71	54.3	19.2	73.5
			Dry Land					
0	22.4	1317	1.0225	8.92	0.34	22.5	4.5	27.0
25	29.9	1969	0.9225	9.84	0.40	33.2	7.9	41.1
50	28.1	1837	0.9175	10.67	0.51	33.8	9.4	43.2
75	35.8	2534	0.8475	11.04	0.46	44.6	11.7	56.3
100	32.0	2379	0.8125	12.19	0.56	44.0	13.3	57.3
150	32.4	2333	0.8375	12.88	0.69	47.1	16.1	63.2
200	39.1	3034	0.7775	13.06	0.69	57.6	20.9	78.5
300	37.2	2814	0.7350	13.62	0.96	52.5	27.0	79.5

[1]Soil nitrogen content at seeding was 20 lb NO_3-N/acre to 2 feet.

[2]Grain protein content based on % N at 13.5% moisture x 5.32.

[3]Straw % N on oven dry basis.

Table 1.1.9 The effect of nitrogen fertilization on the yield, nitrogen content, and nitrogen uptake of soft wheat grown under irrigation on field experiments.

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain[1] % Prot.	Straw[2] % N	Nitrogen Uptake (lb/acre)		
	Grain bu/ac	Straw lb/ac				Grain	Straw	Total
	Carlson site (Elstow soil) - Lemhi 62 soft wheat (Soil NO_3-N at seeding = 19 lb/ac to 2 feet)							
0	18.6	948	1.1733	9.66	0.28	20.3	2.7	23.0
25	36.9	2114	1.0950	9.29	0.30	38.7	6.3	45.0
50	43.0	2475	1.0417	9.48	0.29	46.0	7.2	53.2
75	39.6	2396	1.0200	9.71	0.31	43.4	7.4	50.8
100	48.3	2807	1.0683	9.84	0.30	53.6	8.4	62.0
150	47.9	3003	0.9850	9.94	0.39	53.7	11.7	65.4
200	54.7	3099	1.0983	10.53	0.46	65.0	14.3	79.2
300	56.8	3564	0.9750	11.91	0.57	76.3	20.3	96.6
	Niska site (Bradwell soil) - Springfield soft wheat (Soil NO_3-N at seeding = 91 lb/ac to 2 feet)							
0	61.2	5942	0.6117	12.70	0.67	87.7	39.8	127.5
25	59.6	5421	0.6520	12.70	0.60	85.4	32.5	117.9
50	51.1	5137	0.6200	12.65	0.64	72.9	32.9	105.8
75	60.8	5791	0.6300	11.87	0.62	81.4	35.9	117.3
100	61.8	6855	0.5483	13.06	0.75	91.0	51.4	142.4
150	54.5	6372	0.5247	12.60	0.86	77.5	54.8	132.3
200	47.2	5662	0.5033	12.65	0.90	67.3	51.0	118.3
300	53.7	5734	0.6383	13.25	0.97	80.3	55.6	135.9
	Pederson site (Elstow soil) - Lemhi 62 soft wheat (Soil NO_3-N at seeding = 52 lb/ac to 2 feet)							
0	47.3	3022	0.9433	9.48	0.37	50.6	11.2	61.8
25	53.2	3468	0.9517	10.49	0.34	62.9	11.8	74.7
50	61.2	3726	0.9967	10.95	0.45	75.6	16.8	92.4
75	66.1	4326	0.9367	11.59	0.61	86.4	26.4	112.8
100	63.9	4067	0.9433	11.78	0.54	84.9	22.0	106.9
150	68.8	4780	0.8700	13.20	0.70	102.4	33.5	135.9
200	60.7	4083	0.9000	13.06	0.75	89.4	30.6	120.0
300	65.2	4625	0.8567	13.02	0.80	95.7	37.0	132.7

[1]Grain protein content based on % N at 13.5% moisture x 5.32.

[2]Straw % N on oven dry basis.

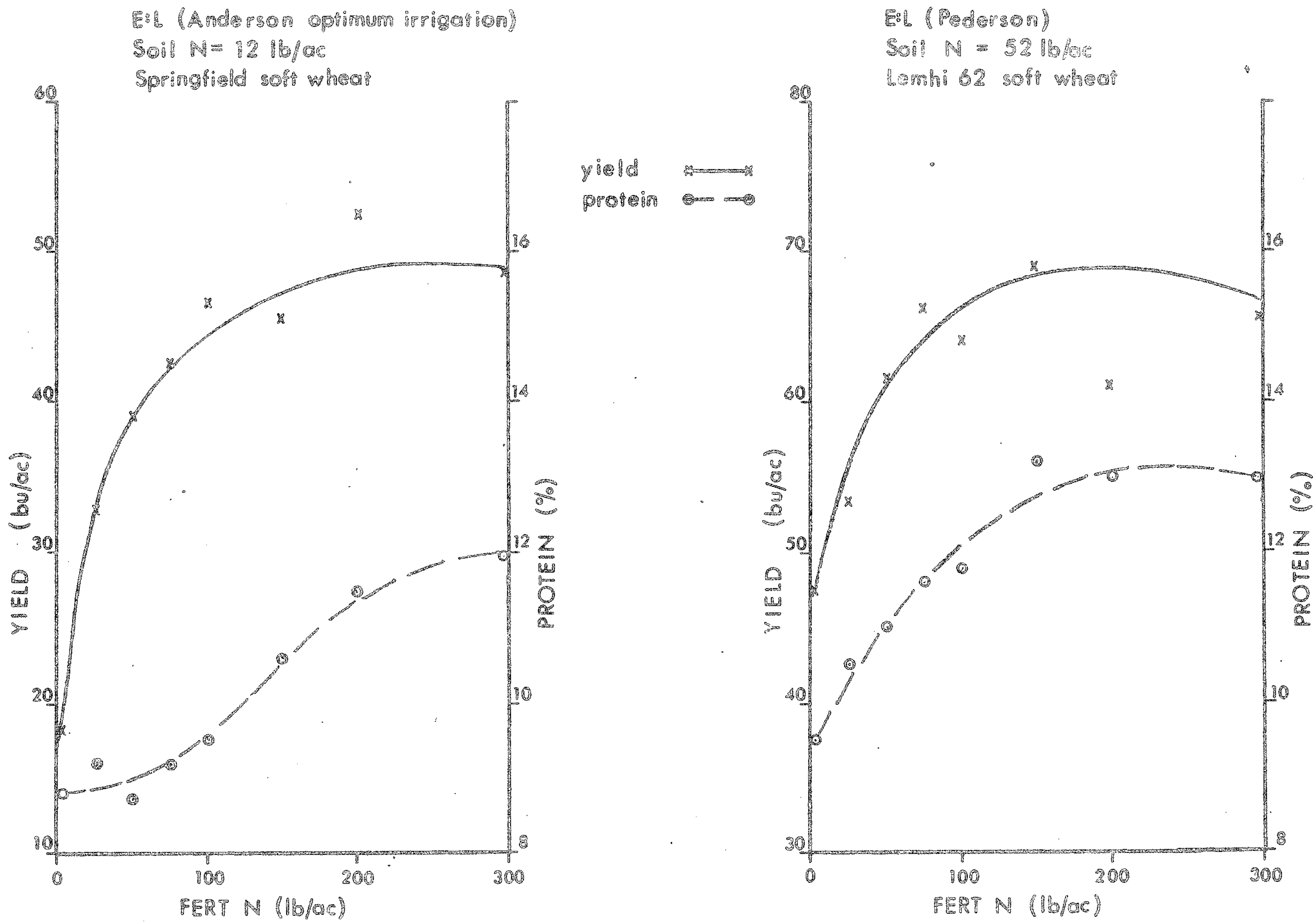

FIG.1.1.2 The effect of nitrogen fertilization on the yield and protein content of soft wheat.

around 52 and 44 bu/acre were achieved under optimum irrigation on the Elstow and Asquith sites respectively, as opposed to maximum yields of around 26 and 39 bu/acre for the dryland plots on the same site. The greatest difference was apparent on the Elstow site where optimum irrigation plots received 9.9 inches of irrigation water and a total of 13.7 inches of moisture during the growing season. The Asquith site received 5.5 inches of irrigation water and total moisture of 11.3 inches.

The grain/straw ratio on some sites tends to decline with increased rates of fertilizer nitrogen applied, while on other sites no definite trend is apparent. There are, however, two observations which are immediately apparent in regards to this data. The grain/straw ratio tends to be lowest on sites with the highest initial NO_3-N levels (Niska site and Pederson site), which would indicate that higher amounts of available nitrogen result in larger increases in total vegetative plant matter production than increases in seed production. Also, in the data from the water control experiments, it is apparent that the grain/straw ratio is higher on the optimum irrigation plots than on the dryland plots (particularly on the Elstow site) which would suggest that grain production is more efficient when more moisture is available for crop growth.

Similar to results from the barley plots and results from previous years, grain protein content and straw nitrogen content tends to increase with increases in nitrogen fertilization. Largest increases occur at nitrogen application rates above the levels required for maximum yields. Protein contents tend to be highest on plots with relatively high initial NO_3-N contents

(Niska and Pederson sites) and also tend to be higher where moisture is limiting. Since high protein contents are undesirable in soft wheat, it is essential to have a knowledge of the level of available NO_3-N in the soil so that grain of too high a protein content will not be produced as a result of over fertilization.

Total nitrogen uptake by soft wheat increased in direct response to rate of fertilizer nitrogen applied.

<u>Response of rapeseed to nitrogen fertilization</u>

The yield, nitrogen uptake and oil content data for the rapessed plots are presented in Tables 1.1.10, 1.1.11 and 1.1.12. Overall yields of rapeseed were low and disappointing, particularly on the irrigated water control plots where maximum yields of 33 bu/acre were obtained on both plots at the 75 lb N/acre application rate. Yields on the dryland plots were totally unacceptable. On the Pederson field site a very meagre maximum yield of 25 bu/acre was obtained. A high occurrence of volunteer flax and a lack of moisture (the crop was only irrigated once) probably combined to limit the yields on this site to these low levels. On the remaining two sites, both of which had an initial soil NO_3-N content in the medium range yields jumped from around 20 bu/acre in the check treatments to more than 40 bu/acre at high nitrogen application rates.

Certain problems arose in field plot studies with rapeseed which may account in part for the poor yields recorded. All plots, and in particular the water control plots, showed very spotty germination. This may have been the result of soil compaction caused by spreading fertilizer after seeding. A second problem

Table 1.1.10 The effect of nitrogen fertilization on the yield, nitrogen content, oil content, and nitrogen uptake of Midas rapeseed grown on Elstow soil[1] (Anderson site).

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N	Grain % Oil	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac					Grain	Straw (lb/acre)	Total
				Optimum Irrigation					
0	11.7	1813	0.33	18.9	0.32	47.0	18.9	5.8	24.7
25	21.2	2726	0.39	19.2	0.29	45.6	34.9	7.9	42.8
50	27.0	3365	0.39	20.1	0.38	44.1	46.5	12.8	59.3
75	33.2	4110	0.40	20.6	0.39	43.9	58.7	16.0	74.7
100	27.1	2494	0.39	20.6	0.34	43.3	48.2	11.9	60.1
150	30.5	3727	0.39	21.4	0.46	42.5	56.0	17.2	73.2
200	30.5	3855	0.40	22.1	0.55	41.9	57.8	21.2	79.0
300	32.4	3985	0.41	22.3	0.67	41.3	62.0	26.7	88.7
				Dry Land					
0	2.5	882	0.14	23.2	0.46	38.6	5.0	4.1	9.1
25	2.0	988	0.10	24.4	0.71	36.4	4.2	7.0	11.2
50	3.0	1219	0.12	24.4	0.59	36.0	6.3	7.2	13.5
75	2.3	938	0.12	24.1	0.95	37.1	4.8	8.9	13.7
100	3.1	1195	0.13	24.6	0.81	36.0	6.5	9.7	16.2
150	2.7	1183	0.11	24.6	0.88	36.6	5.7	10.4	16.1
200	3.2	1122	0.14	24.5	0.96	36.9	6.7	10.8	17.5
300	1.6	930	0.09	24.7	1.04	36.9	3.4	9.7	13.1

[1]Soil nitrogen content at seeding was 12 lb NO_3-N/acre to 2 feet.

Table 1.1.11 The effect of nitrogen fertilization on the yield, nitrogen content, oil content, and nitrogen uptake of Midas rapeseed grown on Asquith soil[1] (Davison site).

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N	Grain % Oil	Nitrogen Uptake		
	Grain bu/ac	Straw lb/ac					Grain	Straw (lb/acre)	Total
				Optimum Irrigation					
0	9.6	1326	0.36	18.6	0.34	46.0	15.3	4.5	19.8
25	22.4	2878	0.38	18.3	0.37	46.4	35.2	10.7	45.9
50	26.8	3185	0.42	19.7	0.43	43.9	45.3	13.7	59.0
75	33.0	3670	0.44	20.4	0.46	43.4	57.7	16.9	74.6
100	22.1	2585	0.43	20.0	0.60	44.0	37.9	15.5	53.4
150	24.6	2945	0.43	21.2	0.69	42.5	44.7	20.3	65.0
200	28.4	3272	0.44	21.6	0.71	41.8	52.6	23.2	75.8
300	25.5	2958	0.42	22.3	0.96	40.9	48.8	28.4	77.2
				Dry Land					
0	6.4	921	0.35	17.7	0.32	47.4	9.7	3.0	12.7
25	9.1	1235	0.37	19.3	0.31	45.0	15.1	3.8	18.9
50	11.2	1248	0.41	21.4	0.43	41.0	20.6	5.8	26.4
75	13.1	1612	0.39	21.2	0.42	41.6	23.8	6.8	30.6
100	14.8	1656	0.45	22.2	0.69	40.2	28.2	11.4	39.6
150	10.7	1327	0.40	23.1	0.59	39.3	21.2	7.8	29.0
200	11.3	1316	0.43	23.0	0.76	39.7	22.3	10.0	32.3
300	12.6	1531	0.39	22.8	0.82	39.7	24.6	12.6	37.2

[1] Soil nitrogen content at seeding was 20 lb NO_3-N/acre to 2 feet.

Table 1.1.12 The effect of nitrogen fertilization on the yield, nitrogen content, oil content, and nitrogen uptake of rapeseed grown under irrigation on field experiments.

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N	Grain % Oil	Nitrogen Uptake (lb/acre)		
	Grain bu/ac	Straw lb/ac					Grain	Straw	Total
Pederson site (Elstow soil) - Zephyr rapeseed (Soil NO_3-N at seeding = 22 lb/ac to 2 feet)									
0	12.2	2028	0.28	20.1	0.34	42.4	21.0	6.9	27.9
25	15.1	2884	0.26	20.1	0.35	42.6	26.0	10.1	36.1
50	14.8	2772	0.26	20.6	0.40	42.1	26.2	11.1	37.3
75	21.9	3562	0.30	20.8		41.6	39.1		
100	18.8	3504	0.26	20.7	0.38	41.6	33.4	13.3	46.7
150	25.2	4151	0.30	21.4	0.39	41.6	46.3	16.2	62.5
200	25.9	4554	0.29	22.5	0.60	39.2	50.0	27.3	77.3
300	28.0	4548	0.31	23.5	0.70	38.1	56.4	31.8	88.2
Niska site (Elstow soil) - (Soil NO_3-N at seeding = 41 lb/ac to 2 feet)									
0	24.5	3373	0.37	21.0	0.55	42.5	44.1	18.6	62.7
25	24.2	3736	0.34	20.3	0.34	43.7	42.1	12.7	54.8
50	30.8	4105	0.38	22.7	0.71	40.0	60.0	29.2	89.2
75	36.4	4853	0.37	23.1	0.59	39.2	72.1	28.6	100.7
100	32.2	4607	0.35	23.1	0.43	39.6	63.8	19.8	83.6
150	37.1	4986	0.38	22.9	0.46	39.8	72.9	22.9	95.8
200	41.5	5418	0.38	23.8	0.78	38.3	84.7	42.3	127.0
300	33.5	4916	0.34	24.5	0.96	37.2	70.4	47.2	117.6
Carlson site (Bradwell soil) - Torch rapeseed (Soil NO_3-N at seeding = 43 lb/ac to 2 feet)									
0	20.8	2260	0.46	21.7	0.67	40.7	38.7	15.1	53.8
25	26.8	2801	0.47	21.6	0.64	40.3	49.7	17.9	67.6
50	35.5	3389	0.52	22.4	0.63	39.9	68.2	21.4	89.6
75	28.5	2859	0.50	22.3	0.65	40.2	54.5	18.6	73.1
100	30.7	2985	0.51	22.6	0.71	39.4	59.5	21.2	80.7
150	33.7	3305	0.51	23.3	1.06	38.9	67.3	35.0	102.3
200	35.2	3144	0.56	23.7	1.11	38.2	71.6	34.9	106.5
300	46.4	4455	0.53	24.2	1.33	37.7	96.3	59.3	155.6

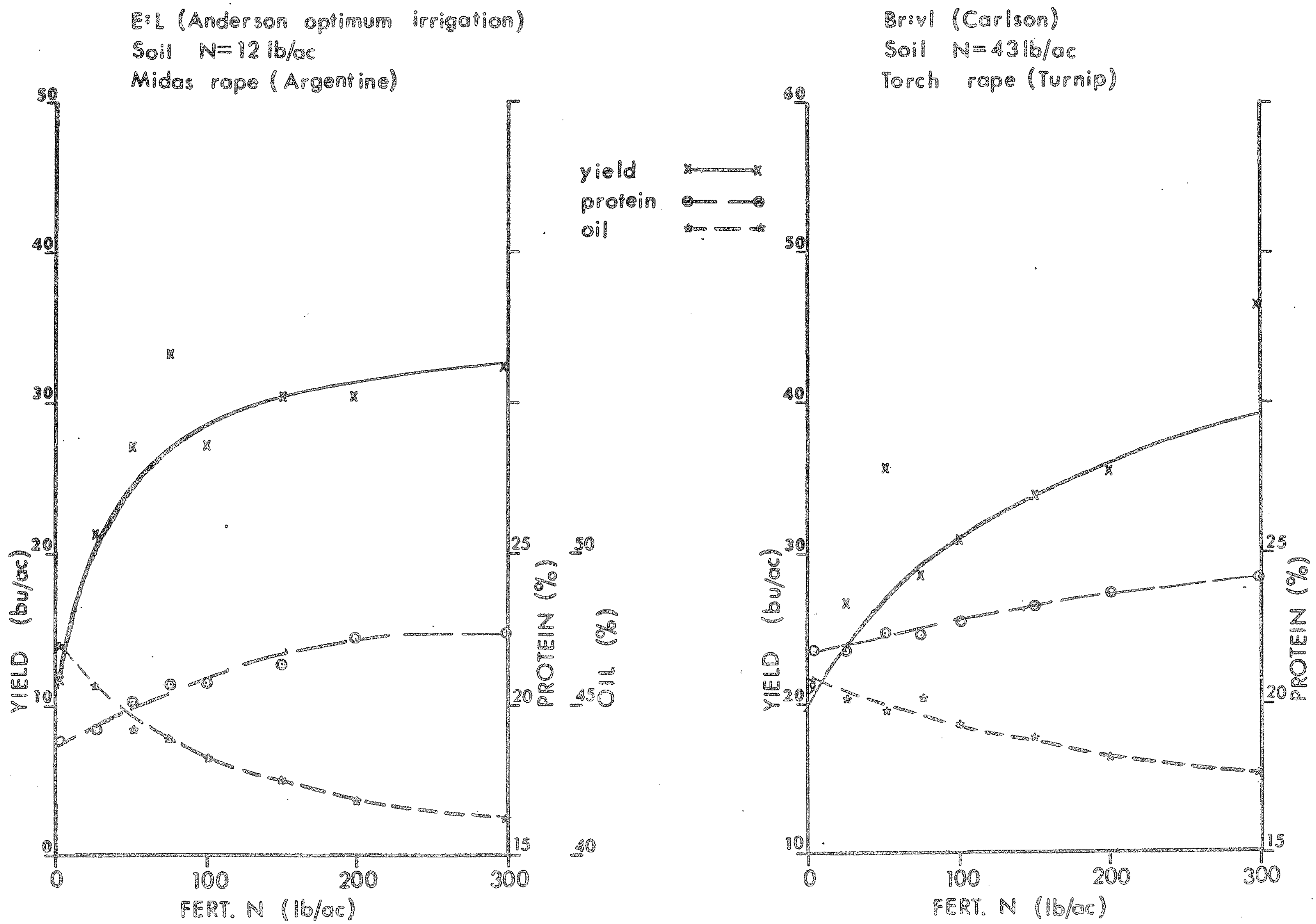

FIG.1.13 The effect of nitrogen fertilization on the yield, protein and oil content of rapeseed.

which again affected the water control plots to a larger extent than the field plots was the infestation by flea beetles, and on the Anderson site an infestation of grasshoppers which severely damaged seed pods. A third problem, which relates to all of the plots, arose at harvest time when different treatments in the same plot matured at different times. This resulted in some of the treatments being overripe with the seed pods prone to shattering while other treatments were not completely ripe and some seed shrinking may have occurred.

Data on the ratio of grain/straw production show on all plots a relatively constant ratio regardless of nitrogen application rates. This indicates for rapeseed that seed production is increasing in direct proportion to total plant material production. Differences in grain/straw ratio between plots may be attributed to such variables as different rapeseed varieties or differences in irrigation scheduling.

The protein content of the rapeseed grain and nitrogen content of the rapeseed straw generally increase with increased rates of applied nitrogen. On the three sites with relatively low initial NO_3-N contents (Anderson, Davison, Pederson) protein contents increased markedly only at higher application rates, while on the remaining sites, where initial nitrogen contents were in the medium range, protein contents tended to increase with each increment of applied nitrogen. Overall protein contents tended to be higher on these latter two sites. On the water control plot there was a considerable difference in the protein contents between irrigated and non-irrigated rapeseed, with the non-irrigated rapeseed containing higher protein.

At all locations, the oil content of rapeseed declined as rates of applied nitrogen increased. Highest oil contents were obtained on the water control experiments where Midas rapeseed was grown, while the Torch rapeseed on the Carlson site contained the lowest oil content.

Responses to single and split nitrogen applications

In addition to the basic spring broadcast nitrogen applications two treatments were included in each plot of all crops in which half of the total nitrogen to be applied was broadcast at seeding time and the remaining half was broadcast in late June. The rates of total nitrogen applied in these treatments were 100 and 150 lbs N/acre. Data on the effect of the single vs split applications of nitrogen on the yield and nitrogen uptake (and in the case of rapeseed, oil content) are presented in Table 1.1.13 for barley, Table 1.1.14 for soft wheat and Table 1.1.15 for rapeseed. Yield results comparing these two types of applications are somewhat variable, and there appears to be no consistent trend towards yield being higher for either the single or split application for any of the three crops. In some instances the split application gave higher yields, in other instances the single application appeared more favorable, but in many instances there was virtually little or no difference between the two types of applications.

There appears, however, to be a fairly consistent trend in all crops on the effect of single and split nitrogen applications on the protein content of grain and the nitrogen content of straw, whereby the split application generally results in both higher grain protein and higher straw nitrogen contents. In the case of barley

Table 1.1.13 The effect of single and split applications of fertilizer nitrogen on the yield, nitrogen content, and nitrogen uptake of barley grown under irrigation.

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N	Nitrogen Uptake (lb/acre)		
	Grain bu/ac	Straw lb/ac				Grain	Straw	Total
Anderson Water Control Experiment (Elstow soil)								
			Optimum Irrigation					
100-single	54.4	2741	0.9550	8.87	0.41	39.8	11.2	51.0
-split	71.1	3143	1.0950	12.25	0.71	71.7	22.3	94.0
150-single	62.9	3436	0.9800	9.88	0.45	56.3	15.5	71.8
-split	70.7	3294	1.0450	12.50	0.67	72.8	22.1	94.9
			Dry Land					
100-single	33.0	1722	0.9350	11.84	0.71	32.2	12.2	44.0
-split	25.1	1135	1.0600	15.07	0.74	31.1	8.4	39.5
150-single	21.9	1725	0.7150	14.46	0.74	26.1	12.8	38.9
-split	27.2	1247	1.0800	14.26	0.69	31.9	8.6	40.5
Davison Water Control Experiment (Asquith soil)								
			Optimum Irrigation					
100-single	58.6	2702	1.0450	10.53	0.55	50.8	14.9	65.7
-split	58.4	2567	1.0950	11.84	0.79	56.9	20.3	77.2
150-single	59.5	2609	1.0950	11.94	0.67	58.5	17.5	76.0
-split	59.3	2561	1.1175	12.95	0.78	63.2	20.0	83.2
			Dry Land					
100-single	42.1	1758	1.1525	11.84	0.71	41.0	12.5	53.5
-split	41.6	1680	1.1925	14.11	0.89	48.3	15.0	63.3
150-single	49.2	2171	1.0925	13.31	0.80	53.9	17.4	71.3
-split	43.7	1816	1.1575	13.91	0.95	50.1	17.3	67.4
Carlson Field Experiment (Elstow soil)								
100-single	80.3	3543	1.0900	13.46	1.09	89.0	38.6	127.6
-split	77.8	3602	1.0517	12.95	1.13	83.0	40.7	123.7
150-single	81.1	3911	1.0067	12.90	1.06	86.1	41.5	127.6
-split	86.9	3574	1.1867	13.31	1.34	92.2	47.9	143.1
Stranden Field Experiment (Elstow soil)								
100-single	56.2	3110	0.9950	8.62	0.41	39.9	12.8	52.7
-split	46.4	2877	0.8330	11.69	0.58	44.7	16.7	61.4
150-single	62.0	3322	0.9900	10.94	0.54	55.9	17.9	73.8
-split	53.8	3320	0.8633	12.40	0.80	54.9	26.6	81.5

Table 1.1.14 The effect of single and split applications of fertilizer nitrogen on the yield, nitrogen content, and nitrogen uptake of soft wheat grown under irrigation

N Applied lb/ac	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain % Prot.	Straw % N	Nitrogen Uptake Grain (lb/acre)	Nitrogen Uptake Straw (lb/acre)	Nitrogen Uptake Total (lb/acre)
Anderson Water Control Experiment (Elstow soil)								
			Optimum Irrigation					
100-single	46.4	2674	1.0525	9.52	0.43	49.8	11.5	61.3
-split	35.3	2370	0.9050	11.13	0.53	44.3	12.6	56.9
150-single	45.3	2732	0.9975	10.58	0.52	54.1	14.2	68.3
-split	48.6	3204	0.9325	12.33	1.20	67.6	38.5	106.1
			Dry Land					
100-single	19.1	1554	0.7250	12.14	0.58	26.2	9.0	35.2
-split	21.0	1602	0.7775	12.14	0.53	28.8	8.5	37.3
150-single	21.7	1836	0.6975	12.97	0.60	31.7	11.0	42.7
-split	20.9	1704	0.7250	12.93	0.59	30.5	10.1	40.6
Davison Water Control Experiment (Asquith soil)								
			Optimum Irrigation					
100-single	38.4	2426	0.9600	10.4	0.43	45.0	10.4	55.4
-split	37.2	2544	0.8801	10.67	0.54	44.8	13.7	58.5
150-single	42.0	2849	0.8900	11.13	0.57	52.7	16.2	68.9
-split	41.7	2751	0.9125	11.73	0.68	55.2	18.7	73.9
			Dry Land					
100-single	32.0	2379	0.8125	12.19	0.56	44.0	13.3	57.3
-split	33.2	2175	0.9175	13.16	0.57	49.3	12.4	61.7
150-single	32.4	2333	0.8375	12.88	0.69	47.1	16.1	63.2
-split	34.2	2243	0.150	13.34	0.63	51.5	14.1	65.6
Carlson Field Experiment (Elstow soil)								
100-single	48.3	2807	1.0683	9.84	0.30	53.6	8.4	62.0
-split	48.1	2651	1.2033	10.72	0.50	58.2	13.3	71.5
150-single	47.9	3003	0.9850	9.94	0.34	53.7	11.7	65.4
-split	51.1	3445	0.9483	11.59	0.48	66.8	16.5	83.3
Pederson Field Experiment (Elstow soil)								
100-single	63.9	4067	0.9433	11.78	0.54	84.9	22.0	106.9
-split	66.3	4182	0.9683	12.10	0.53	90.5	22.2	112.7
150-single	68.8	4780	0.8700	13.20	0.70	102.4	33.5	135.9
-split	66.4	4522	0.9017	11.41	0.53	85.5	24.0	109.5
Niska Field Experiment (Elstow soil)								
100-single	61.8	6855	0.5483	13.06	0.75	91.0	51.4	142.4
-split	53.1	6404	0.4607	11.96	0.81	71.6	51.9	123.5
150-single	54.5	6372	0.5247	12.60	0.86	77.5	54.8	132.3
-split	54.3	5847	0.5583	13.20	0.96	80.8	56.1	136.9

Table 1.1.15 The effect of single and split applications of fertilizer nitrogen on the yield, nitrogen content, and nitrogen uptake of rapeseed grown under irrigation.

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N	Grain % Oil	Nitrogen Uptake (lb/acre)		
	Grain bu/ac	Straw lb/ac					Grain	Straw	Total
Anderson Water Control Experiment (Elstow soil)									
				Optimum Irrigation					
100-single	27.3	3494	0.39	20.6	0.34	43.3	48.2	11.9	60.1
-split	20.3	2431	0.42	21.4	0.54	42.2	37.3	13.1	50.4
150-single	30.5	3727	0.39	21.4	0.46	42.5	56.0	17.2	73.2
-split	29.7	3731	0.40	22.7	0.53	41.2	57.8	19.8	77.6
				Dry Land					
100-single	3.1	1195	0.13	24.6	0.81	36.0	6.5	9.7	16.2
-split	1.9	797	0.11	24.2	0.94	37.1	3.9	7.5	11.4
150-single	2.7	1183	0.11	24.6	0.88	36.6	5.7	10.4	16.1
-split	2.1	832	0.13	24.3	0.91	37.0	4.4	7.6	12.0
Davison Water Control Experiment (Asquith soil)									
100-single	22.1	2585	0.43	20.0	0.60	44.0	37.9	15.5	53.4
-split	35.1	3718	0.47	21.3	0.68	42.7	64.1	25.3	89.4
150-single	24.6	2945	0.43	21.2	0.69	42.5	44.7	20.3	65.0
-split	33.1	3356	0.49	21.6	0.60	42.4	61.3	20.1	81.5
				Dry Land					
100-single	14.8	1656	0.45	22.2	0.69	40.2	28.2	11.4	39.6
-split	13.6	1548	0.44	22.3	0.64	40.0	26.0	9.9	35.9
150-single	10.7	1327	0.40	23.1	0.59	39.3	21.2	7.8	29.0
-split	10.6	1411	0.40	23.1	0.85	39.4	21.0	12.0	33.0
Carlson Field Experiment (Elstow soil)									
100-single	30.7	2985	0.51	22.6	0.71	39.4	59.5	21.2	80.7
-split	35.8	3483	0.51	22.9	0.79	39.0	70.3	27.5	97.8
150-single	33.7	3305	0.51	23.3	1.06	38.9	67.3	35.0	102.3
-split	37.5	3600	0.52	23.5	1.10	38.0	75.6	39.6	115.2
Pederson Field Experiment (Elstow soil)									
100-single	18.8	3504	0.26	20.7	0.38	41.6	33.4	13.3	46.7
-split	18.6	3357	0.27	21.6		40.9	55.0		
150-single	25.2	4151	0.30	21.4	0.39	41.6	46.3	16.2	62.5
-split	27.9	4890	0.29	23.0	0.69	38.9	55.4	33.0	88.5
Niska Field Experiment (Bradwell soil)									
100-single	32.2	4607	0.35	23.1	0.43	39.6	63.8	19.8	83.6
-split	30.0	4013	0.38	23.9	0.50	38.3	61.5	20.1	81.6
150-single	37.1	4986	0.38	22.9	0.46	39.8	72.9	22.9	95.8
-split	38.1	5081	0.37	24.2	0.82	37.9	79.1	41.7	120.7

these trends appear reasonably consistantly, and the average increase for all plots in % protein of the grain is around 1.5 percent greater from the split over the single nitrogen application. The average increase in straw nitrogen content is greater than 0.14 percent.

For wheat, a similar situation is evident. Grain from split nitrogen application treatments contained an average of 0.5 percent higher protein than that from the single application treatment. The corresponding straw nitrogen content is approximately 0.1 percent higher.

In the case of rapeseed, split application results in an average increase in protein of approximately 0.5 percent with a corresponding average decline in oil content of approximately 0.75 percent.

For all three crops on the water 1 plots of both the Type A water control experiments, treatments were included in which ^{15}N labelled fertilizer was applied in split applications to determine the relative effectiveness of the two times of application. In one treatment 75 lb/acre of ^{15}N enriched ammonium nitrate was applied at seeding and 75 lbs N/acre of non-tagged ammonium nitrate was applied in late June. In the second treatment 75 lbs N/acre of non-tagged fertilizer was applied at seeding and 75 lbs N/acre of tagged material was applied in mid-June. Data on the percent plant nitrogen derived from the tagged fertilizer, A values, and percent uptake of the tagged fertilizer for both applications in all crops is presented in Table 1.1.16. These results indicate that more efficient use is made by all crops of the fertilizer applied in mid-season over that applied at seeding. Without

Table 1.1.16 The effect of time of application on the uptake of fertilizer nitrogen by irrigated barley, soft wheat, and rapeseed as measured by ^{15}N assay techniques.

Time of Application[1]	% NDFF[2]		"A" Value (lb/acre)		% Uptake[3]		
	Grain	Straw	Grain	Straw	Grain	Straw	Total
	Barley - Anderson site (Elstow soil)						
Seeding	20.4	28.3	300	194	19.6	3.9	23.5
Mid-season	38.2	23.2	122	253	25.9	3.2	29.1
	Barley - Davison site (Asquith soil)						
Seeding	20.8	27.5	288	201	12.5	3.3	15.8
Mid-season	36.1	24.3	134	237	20.5	3.0	23.5
	Soft Wheat - Anderson site						
Seeding	24.0	32.0	239	161	14.5	5.2	19.7
Mid-season	38.3	30.0	122	181	23.7	4.4	28.1
	Soft Wheat - Davison site						
Seeding	27.4	30.9	200	169	16.1	4.7	20.8
Mid-season	31.0	25.1	168	235	17.9	4.2	22.1
	Rapeseed - Anderson site						
Seeding	21.8	23.0	278	260	1.2	5.1	6.3
Mid-season	35.6	29.5	139	186	1.8	5.0	6.8
	Rapeseed - Davison site						
Seeding	26.5	26.4	218	218	9.3	4.0	13.3
Mid-season	32.2	30.4	160	130	16.5	6.3	22.8

[1]Time of application of tagged fertilizer material.

[2]Percent of the plant nitrogen derived from the tagged fertilizer.

[3]Percent uptake of tagged nitrogen fertilizer.

exception, for the grain portion of all crops on both sites, a greater percentage of the nitrogen in the grain is derived from the fertilizer applied in mid-season than that applied at seeding. The A values, therefore, are lower in the grain for the mid-season applied fertilizer nitrogen with a corresponding higher grain N uptake. In the case of the values for the straw, both the barley and soft wheat on both sites have a lower % nitrogen derived from fertilizer in the mid-season application with a corresponding higher A value. Such results were not noted in data from the two previous yields. However, overall total plant nitrogen uptake is greater from the mid-season application than from the spring application.

Responses to other nutrients

Nitrogen was the major nutrient under study in these investigations. However, additional treatments were included in all experiments to investigate the possibility of phosphorus, potassium, and sulphur deficiencies.

Phosphorus was applied to all plots at 40 lbs P_2O_5/acre barley and wheat and 30 lbs P_2O_5/acre for rapeseed with the seed (or in the case of Type C experiments as applied by the farmer). One treatment was included on all plots in which an additional 110 lbs P_2O_5/acre was broadcast to determine whether a further response to additional phosphorus may be realized. Data on the effect of this additional phosphorus application on the yield and nitrogen content of the three crops from the various sites are presented in Table 1.1.17, 1.1.18 and 1.1.19. Results appear to indicate that in most cases the amount of phosphate applied with the seed was sufficient for soft wheat and rapeseed since no consistent yield

Table 1.1.17 The effect of additional phosphorus fertilizer on the yield and nitrogen content of irrigated barley.

Site		P Applied lb/ac[1]	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N
			Grain bu/ac	Straw lb/ac			
Anderson (Elstow)	Optimum Irrigation	40	68.9	3497	0.9400	11.44	0.56
		40+110[2]	82.6	4450	0.8950	11.29	0.60
	Dryland	40	28.8	1579	0.8800	14.52	0.90
		40+110	34.6	1605	1.0425	14.16	0.81
Davison (Asquith)	Optimum Irrigation	40	60.5	2786	1.0750	12.1	0.81
		40+110	73.1	3284	1.0625	12.35	0.95
	Dryland	40	45.3	2150	1.0225	14.06	0.95
		40+110	42.7	2047	1.0025	13.81	1.09
Carlson (Elstow)		40	90.0	3664	1.1917	13.71	1.05
		40+110	92.2	2932	1.1567	13.96	1.38
Pederson (Elstow)		40	68.1	4762	0.7383	14.01	0.90
		40+110	65.5	5075	0.6267	15.02	0.85
Stranden (Elstow)		40	62.1	3675	0.8967	10.79	0.46
		40+110	68.0	3626	0.9567	11.04	0.64

[1] All treatments received 200 lb N/acre.

[2] 40 lb P_2O_5/acre applied with the seed and 115 lb P_2O_5/acre broadcast.

Table 1.1.18 The effect of additional phosphorus fertilizer on the yield and nitrogen content of irrigated soft wheat.

Site		P Applied lb/ac[1]	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain % Prot.	Straw % N
Anderson (Elstow)	Optimum Irrigation	40	52.3	3035	1.0400	11.50	0.57
		40+110[2]	60.4	3385	1.0725	11.13	0.69
	Dryland	40	26.4	2061	0.7725	13.06	0.61
		40+110	23.9	1992	0.7150	13.75	0.72
Davison (Asquith)	Optimum Irrigation	40	43.7	2850	0.9200	12.05	0.64
		40+110	41.5	3244	0.7650	11.52	0.77
	Dryland	40	39.1	3034	0.7750	13.06	0.69
		40+110	41.4	3545	0.7150	13.25	0.92
Carlson (Elstow)		40	54.7	3099	1.0983	10.53	0.46
		40+110	46.8	3129	0.9267	10.99	0.60
Pederson (Elstow)		40	60.7	4083	0.9000	13.06	0.75
		40+110	63.7	4145	0.9450	13.06	0.76
Niska (Bradwell)		40	47.2	5662	0.5033	12.65	0.90
		40+110	44.0	6286	0.4167	12.47	1.09

[1] All treatments received 200 lb N/acre.

[2] 40 lb P_2O_5/acre applied with the seed and 115 lb P_2O_5/acre broadcast.

Table 1.1.19 The effect of additional phosphorus fertilizer on the yield and nitrogen and oil content of irrigated rapeseed.

Site		P Applied lb/ac[1]	Yield		Grain/ Straw Ratio	Grain % Prot.	Straw % N	Grain % Oil
			Grain bu/ac	Straw lb/ac				
Anderson (Elstow)	Optimum Irrigation	30	30.5	3855	0.40	22.1	0.55	41.9
		30+110[2]	28.9	3753	0.39	21.6	0.44	42.2
	Dryland	30	3.2	1122	0.14	24.5	0.96	36.9
		30+110	2.3	976	0.11	24.6	1.08	36.9
Davison (Asquith)	Optimum Irrigation	30	28.4	3272	0.44	21.6	0.71	41.8
		30+110	32.7	4016	0.40	21.9	0.96	41.6
	Dryland	30	11.3	1316	0.43	23.0	0.76	39.7
		30+110	13.3	1843	0.36	23.0	0.74	39.3
Carlson (Elstow)		30	35.2	3144	0.56	23.7	1.11	38.2
		30+110	38.8	3653	0.53	23.8	1.37	37.7
Pederson (Elstow)		30	25.9	4554	0.29	22.5	0.60	39.2
		30+110	28.1	4787	0.29	23.0	0.69	39.2
Niska (Bradwell)		30	41.5	5418	0.38	23.8	0.75	38.3
		30+110	31.4	4381	0.36	24.9	0.88	36.9

[1] All treatments received 200 lb N/acre.

[2] 30 lb P_2O_5/acre applied with the seed and 115 lb P_2O_5/acre broadcast.

increases were noted with additional phosphorus. For barley, however, there is an indication that additional phosphorus was beneficial since in all but one case yields of irrigated barley were increased in amounts of from approximately 2 to 14 bu/acre. Similar results were noted in results from the experiments in 1971. This would indicate that additional phosphorus may be required for barley when high rates of nitrogen are used and the overall yield potential is high.

No consistent differences were noted in the grain protein or straw nitrogen content as a result of the additional phosphorus application.

Various treatments were included in these experiments in which applications of potassium and sulphur were made. Results on the effects of these treatments on the yields and nitrogen content are presented in Table 1.1.20, 1.1.21 and 1.1.22. These data indicate no consistent yield response of any of the crops to the potassium or sulphur. The soil test levels for potassium were all reasonably high so response to applied potassium would not have been expected. The SO_4-S content of most sites would, by present standards, appear sufficient except possibly on the Davison site, where response of rapeseed to applied sulphur may have been expected. No sulphur response was observed. It is probable that sulphur in the irrigation water was sufficient to provide for any crop requirements not supplied by the soil.

CONCLUSIONS

On the basis of the data obtained, a number of conclusions relating to practical farm management practices can be made.

1) The level of nitrogen available for plant growth is a major

Table 1.1.20 The effect of potassium and sulphur fertilization on the yield and nitrogen content of irrigated barley.

Site		Nutrients Applied[1] K_2O (lb/acre)	S	Yield Grain bu/ac	Straw lb/ac	Grain/ Straw Ratio	Grain % Prot.	Straw % N
Anderson (Elstow)	Optimum Irrigation	0	0	82.6	4450	0.8950	11.29	0.60
		120	0	78.5	3894	0.9700	12.20	0.58
		120	60	74.5	3718	0.9675	11.54	0.68
	Dryland	0	0	34.6	1605	1.0425	14.16	0.81
		120	0	31.7	1475	1.0525	13.96	0.90
		120	60	29.1	1330	1.0625	14.41	0.98
Davison (Asquith)	Optimum Irrigation	0	0	73.1	3284	1.0625	12.35	0.95
		120	0	71.5	3329	1.0300	12.05	0.88
		120	60	74.8	3377	1.0625	12.75	0.87
	Dryland	0	0	42.7	2047	1.0025	13.81	1.09
		120	0	40.4	2416	0.8600	13.66	1.00
		120	60	43.9	2370	0.8925	13.41	1.07
Carlson (Elstow		0	0	92.2	3932	1.1567	13.96	1.38
		120	0	78.4	3618	1.1623	14.31	1.23
		0	60	85.1	3912	1.0533	13.15	1.25
		120	60	81.0	3738	1.0817	13.71	1.20
Pederson (Elstow)		0	0	65.5	5075	0.6267	15.02	0.85
		120	0	63.7	4388	0.7283	14.57	1.01
		0	60	60.3	4388	0.6833	14.31	1.05
		120	60	56.0	4184	0.6717	15.37	0.99
Stranden (Elstow)		0	0	68.0	3626	0.9567	11.04	0.64
		120	0	63.0	3791	0.8367	12.05	0.71
		0	60	63.3	4148	0.7633	10.84	0.74
		120	60	67.5	4221	0.8833	12.30	0.76

[1]All treatments received 200 lb N/acre and 150 lb P_2O_5/acre.

Table 1.1.21 The effect of potassium and sulphur fertilization on the yield and nitrogen content of irrigated soft wheat.

Site		Nutrients Applied[1] K_2O (lb/acre)	Nutrients Applied[1] S (lb/acre)	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain % Prot.	Straw % N
Anderson (Elstow)	Optimum Irrigation	0	0	60.4	3385	1.0725	11.13	0.69
		120	0	46.8	3251	0.8650	11.09	0.63
		120	60	48.3	3308	0.8925	12.28	0.71
	Dryland	0	0	23.9	1992	0.7150	13.75	0.72
		120	0	25.5	2000	0.7550	12.70	0.53
		120	60	25.9	1949	0.7825	12.56	0.71
Davison (Asquith)	Optimum Irrigation	0	0	41.5	3244	0.7650	11.52	0.77
		120	0	48.2	3709	0.7750	12.19	0.69
		120	60	50.4	3390	0.8950	11.87	0.74
	Dryland	0	0	41.4	3545	0.7150	13.25	0.92
		120	0	35.0	2905	0.7225	14.12	1.01
		120	60	44.0	3157	0.8375	12.88	0.76
Carlson (Elstow)		0	0	46.8	3129	0.9267	10.99	0.60
		120	0	56.1	3420	1.0033	11.13	0.53
		0	60	49.6	3142	0.9750	11.04	0.56
		120	60	60.5	3644	1.0167	11.36	0.60
Niska (Bradwell)		0	0	44.0	6286	0.4167	12.47	1.09
		120	0	41.1	4814	0.5267	12.79	0.95
		0	60	41.2	5451	0.4550	12.74	1.07
		120	60	43.5	6004	0.4250	13.24	0.97
Pederson (Elstow)		0	0	63.7	4145	0.9450	13.06	0.76
		120	0	68.5	4734	0.8833	12.65	0.76
		0	60	62.4	3994	0.9483	11.91	0.55
		120	60	75.2	4953	0.9450	12.83	0.81

[1]All treatments received 200 lb N/acre and 150 lb P_2O_5/acre.

Table 1.1.22 The effect of potassium and sulphur fertilization on the yield and nitrogen and oil content of irrigated rapeseed.

Site		Nutrients Applied[1] K_2O (lb/acre)	Nutrients Applied[1] S (lb/acre)	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain % Prot.	Straw % N	Grain % Oil
Anderson (Elstow)	Optimum Irrigation	0	0	28.9	3753	0.39	21.6	0.44	42.2
		120	0	34.4	4037	0.43	22.2	0.58	40.9
		120	60	32.8	4257	0.39	22.5	0.68	41.0
	Dryland	0	0	2.3	976	0.11	24.6	1.08	36.9
		120	0	2.5	1003	0.12	24.2	0.99	37.7
		120	60	2.1	1063	0.10	24.3	1.09	26.7
Davison (Asquith)	Optimum Irrigation	0	0	32.7	4016	0.40	21.9	0.96	41.6
		120	0	30.8	3734	0.41	21.8	1.14	41.6
		120	60	31.7	3934	0.41	22.4	0.95	40.8
	Dryland	0	0	13.3	1843	0.36	23.0	0.74	39.3
		120	0	9.6	1313	0.36	23.4	0.74	39.3
		120	60	11.3	1895	0.30	23.0	0.92	39.3
Carlson (Elstow)		0	0	38.8	3654	0.53	23.8	1.37	37.7
		120	0	38.0	3630	0.51	24.0	1.29	36.9
		0	60	38.7	3591	0.54	24.1	1.16	37.5
		120	60	40.0	3871	0.52	23.7	1.28	37.7
Pederson (Elstow)		0	0	28.1	4787	0.29	23.0	0.69	39.2
		120	0	25.5	4183	0.31	23.1	0.66	38.6
		0	60	28.9	4702	0.30	23.0	0.64	38.7
		120	60	31.9	4189	0.38	22.3	0.67	39.3
Niska (Bradwell)		0	0	31.4	4381	0.36	24.4	0.88	36.9
		120	0	33.3	4594	0.36	24.0	0.66	38.1
		0	60	32.1	4251	0.38	24.6	0.95	36.5
		120	60	34.1	4781	0.35	24.3	0.83	37.3

[1] All treatments received 200 lb N/acre and 150 lb P_2O_5/acre.

factor influencing yields of irrigated barley, soft wheat and rapeseed. Additions of fertilizer nitrogen will result in significant increases in crop yields when there are insufficient quantities of available nitrogen present in the soil. Soil testing is the only way to determine nitrogen requirements. The "complete" soil test will often be required but extensive use could be made of the "nitrate-only" test.

2) Care must be taken not to supply crops with nitrogen in amounts greater than is required. An over-supply of nitrogen can result in a) lodging in cereal crops, b) an undesirably high protein content of soft wheat or malting barley, and c) a significant decline in the oil content of rapeseed. Results obtained in these experiments indicate that present recommendations made by the Saskatchewan Soil Testing Laboratory generally result in near optimum crop yields without affecting crop quality.

3) Applying nitrogen in a split application does appear to be economically advantageous since yields do not appear to be increased from split over single nitrogen applications.

4) Current rates of application of phosphorus appear to be adequate for rapeseed and wheat. Further work may be required to determine whether higher rates of phosphorus will be economic for barley.

5) The supplies of potassium and sulphur appear to be adequate for soft wheat, barley and rapeseed production.

1.2 Nutrient requirements of alfalfa

PURPOSE

To determine the nutrient requirements of alfalfa in relation to the measured levels of available nutrients in the soil.

EXPERIMENTAL METHODS

Sites for investigation were selected in 1971 within the South Saskatchewan Irrigation Project on Crown land operated by the Saskatchewan Department of Agriculture. In 1973 this land was leased to local farmers. The sites (Table 1.2.1) were selected to give some range in soil characteristics and development history. Site 1 was an Elstow soil with some salinity at depth. Site 2 was originally an Asquith soil overlying Elstow type parent material. In the levelling process the A horizon, and a major portion of the B horizon, were removed leaving essentially an Elstow type parent material. Alfalfa had been seeded on this site in 1970 and a uniform stand had been obtained but growth was very poor. A third site on which investigations had been conducted for the past two years had to be abandoned in 1973.

The experiments were laid down in April of 1971. The fertilizer treatments were arranged in a randomized complete block design with six replicates. Border-dike irrigation was used at all locations and two of the replicates were placed on each of three border strips. All fertilizer materials were broadcast on the surface with a specially mounted Caminco applicator. The applications took place in late April of 1971, except for the annual treatments in which an additional application was made in mid-April of 1972 and again in early May of 1973. Triple superphosphate (0-45-0) was the source of phosphorus.

Table 1.2.1 Site characteristics of soils selected for irrigated alfalfa study.

	Site 1	Site 2
Legal Location	NE21-28-7-3	NE32-37-7-3
Co-operator	Ziegler	Vestre
Year Seeded	1968	1970
Irrigation Type	Border	Dike
Soil Association	Elstow	Elstow
Texture	Loam	Loam
A Horizon	Intact	Removed
Available N* lb/ac to 2'	81	38
Available P lb/ac to 6"	14	4
Available K lb/ac to 6"	564	214

*Soil analyses are from samples taken in April of 1971.

Potash (0-0-60) was the source of potassium and ammonium nitrate (34-0-0) was the source of nitrogen. Ammonium sulfate (24-0-0) was used where both sulfur and nitrogen were applied. The various treatments used are presented in Table 1.2.2. Inadvertently, Site 1 received a blanket application of approximately 100 lb P_2O_5/acre as monoammonium phosphate (11-55-0) in the fall of 1972.

Each plot was 5 feet by 20 feet. Samples were cut at a height of approximately 3 inches with a 2-foot Mott forage plot harvester over the 20 foot length of the plot. A wet weight of the samples was taken in the field immediately after cutting. A subsample of each treatment was taken and returned to the laboratory for drying. A dry weight of the subsample was taken and the samples ground in preparation for protein analysis.

Soil samples were taken to a depth of 2 feet from odd numbered treatments following the second harvest (August 1973) and dried and ground in preparation for available phosphorus analyses. Unfortunately the samples taken from Site 2 had to be discarded.

RESULTS

The yield data are presented in Table 1.2.3. Overall yields at both locations are unacceptable for irrigated alfalfa. No yield response to any of the treatments was noted at Site 1. At Site 2, where levelling operations had completely removed the A horizon, yield response to applied phosphate were large. The data indicates that a single large application of between 200 and 300 lbs P_2O_5/acre has reduced the ash. Annual applications of between 75 and 100 lbs P_2O_5/acre/year produced yields comparable to the levels of a single application. It would appear possibly then that a single large application of 200 lbs P_2O_5/acre or

Table 1.2.2 Fertility treatments used for alfalfa.

Treatment Number	Pounds per Acre				
	N	P_2O_5	K_2O	S	B
1	0	0	0	0	0
2	0	50	0	0	0
3	0	100	0	0	0
4	0	150	0	0	0
5	0	200	0	0	0
6	0	250	0	0	0
7	0	300	0	0	0
8	0	25 Annual	0	0	0
9	0	50 Annual	0	0	0
10	0	75 Annual	0	0	0
11	0	100 Annual	0	0	0
12	0	100	200	0	0
13	100	100	200	0	0
14	100	100	200	115	0
15	100	100	200	115	2

Table 1.2.3 Yield results for alfalfa.

Trt. No.	P_2O_5 lb/ac	Other Nutrients	Dry Matter Yield (lb/acre) Ziegler Site 1 Cut 1	Ziegler Site 1 Cut 2	Total	Vestre Site 2 Cut 1	Vestre Site 2 Cut 2	Total
1	0		3116	1664	4870	1369	952	2321
2	50		2698	1434	4132	2281	1674	3955
3	100		2796	1773	4569	2746	1999	4745
4	150		2961	1852	4813	2133	1832	3965
5	200		2976	1628	4604	2794	1976	4770
6	250		2976	1642	4618	3048	2218	5266
7	300		2431	1623	4054	3545	2445	5990
8	25[1]		2774	1693	4467	2482	1945	4427
9	50		3187	1608	4795	2565	1715	4280
10	75		2986	1666	4652	2889	2435	5324
11	100		2697	1605	4302	3025	2281	5306
12	100	K	3113	1673	4786	2818	2298	5116
13	100	KN	2745	1502	4247	2879	1829	4708
14	100	KNS	2636	1687	4323	2518	1831	4349
15	100	KNSB	3600	1608	5208	2498	1764	4262

[1] Treatments 8 to 11 are annual applications, therefore over the three year experiment each treatment received a total of 3 times the annual rate of phosphorus.

Table 1.2.4 The effect of phosphorus fertilization on the protein content of alfalfa.

Treatment Number	P_2O_5 lb/ac	Other Nutrients	% Protein[1] Ziegler Site 1 Cut 1	Ziegler Site 1 Cut 2	Vestre Site 2 Cut 1	Vestre Site 2 Cut 2
1	0		15.8	20.4	19.7	19.6
2	50		18.8	20.3	17.6	19.4
3	100		15.3	19.9	18.8	19.6
4	150		18.0	21.4	18.7	20.1
5	200		18.3	20.5	19.3	19.3
6	250		19.3	21.3	18.6	19.2
7	300		14.8	19.1	18.7	19.8
8	25		14.9	19.3	19.5	20.3
9	50		15.6	19.8	18.7	20.0
10	75		17.4	19.7	20.1	18.7
11	100		15.3	21.7	19.8	18.5
12	100	K	18.0	19.0	19.6	18.9
13	100	KN	16.6	22.5	19.4	18.4
14	100	KNS	16.4	21.9	18.4	19.8
15	100	KNSB	15.6	18.6	18.6	19.4

[1]Protein based on % N x 6.25

Table 1.2.5 The effect of phosphorus fertilization on the soil test levels of available phosphorus on Ziegler forage Site 1. (Samples taken August 1973)

P_2O_5 applied (lb/acre)	Depth (in)	Available Soil Phosphorus (lb/acre)
0	0-6	14
	6-12	9
	12-24	8
100	0-6	16
	6-12	9
	12-24	8
200	0-6	25
	6-12	10
	12-24	14
300	0-6	39
	6-12	15
	12-24	16
150[1]	0-6	32
	6-12	8
	12-24	8
300[1]	0-6	36
	6-12	14
	12-24	14

[1]For these treatments 1/3 of the total phosphorus applied was applied in the spring of 1971, 1972 and 1973.

greater will result in a quick reclamation of a low phosphorus area.

No consistent response has been found to potassium, nitrogen, sulphur or boron.

Composite samples of selected treatments were analyzed for protein. The data (Table 1.2.4) indicate that phosphorus fertilization had no effect on the protein content of alfalfa.

The results of soil analysis taken in August of 1973 (Table 1.2.5) indicate some residual effect for rates in excess of 100 lbs P_2O_5/acre for Site 1. The amount of residual phosphorus is comparable from either the single large application or smaller annual applications.

1.3 Nutrient requirements of corn

PURPOSE

To assess the affects of applied nutrients on the yield and quality of irrigated corn.

EXPERIMENTAL METHODS

Three sites were selected for the establishment of corn plots on fields in the South Saskatchewan Irrigation Project. These fields showed a wide range in initial nutrient content (Table 1.3.1) particularly in nitrate nitrogen and to a lesser degree in phosphate content. Corn trials were handled in a similar manner to the Type C cereal trials in that the experiments were superimposed on fields in which cultivation, seeding, weed control, and irrigation was performed by the cooperating farmers. All sites were corrugation irrigated.

Each experimental plot was of the randomized complete block

Table 1.3.1 Results of analyses of soils from sites selected for irrigated corn studies.

Cooperator	Soil Type/ Texture	Depth (in.)	NO_3-N	$NaHCO_3$ Ext. P	$NaHCO_3$ Ext. K	SO_4-S	pH	Cond.
Martyn	E:l	0-6	53	26	490	23	7.4	0.7
		6-12	27	11	290	18	7.7	0.5
		12-24	34	11	590	40	7.9	0.6
Cameron	A:vfsl	0-6	13	5	625	26+	7.8	0.4
		6-12	13	2	300	26+	7.9	0.5
		12-24	17	2	410	26+	8.1	0.7
Pederson	E:l	0-6	7	10	570	10	7.5	0.4
		6-12	10	2	375	16	7.6	0.4
		12-24	10	5	560	28	7.8	0.4

design containing fourteen treatments (Table 1.3.2) replicated six times. Each treatment consisted of four rows of corn, 30 feet long. Treatments included rates of broadcast nitrogen up to 360 lb N/acre, a single rate of additional broadcast phosphorus, potassium and sulphur and two treatments in which the micro-nutrient elements zinc, manganese and copper were applied. Up to 60 lb N/acre was broadcast at spring seeding time. Treatments with higher rates of nitrogen received the remaining nitrogen in late June (approximately 6 weeks after seeding). All seed-placed phosphorus was applied by the cooperating farmers. The micro-nutrient elements zinc and manganese were supplied by the Cominco Zn-M-N-S fertilizer while copper was supplied as copper sulphate. All micronutrients were broadcast approximately two weeks after seeding.

At harvest, (less than 1 week before frost), one row, ten-foot long samples were taken from each treatment. Samples were dried and cobbed with total cob weight being recorded. Sub-samples of cobs were taken from each treatment and bulked for each site. Subsequently, these were ground for D.O.M. (digestible organic matter) and nitrogen analysis.

RESULTS

Yields in terms of total dry matter weight and cob weight for the three plots are presented in Table 1.3.3.

At the time of harvesting, which was less than a week before the first frost, none of the corn plots were mature. The corn at the Martyn site was closest to maturity while at the Pederson site it was most immature. This is reflected both in the overall yields obtained and in the relative yield of cob compared to the

Table 1.3.2 Fertility treatment used for corn experiment.

Treatment Number	Nutrients applied (lb/acre)						
	N	P_2O_5	K_2O	S	Zn	Mn	Cu
1	0	0[1]	0	0	0	0	0
2	30	0	0	0	0	0	0
3	60	0	0	0	0	0	0
4	90[2]	0	0	0	0	0	0
5	120	0	0	0	0	0	0
6	180	0	0	0	0	0	0
7	240	0	0	0	0	0	0
8	360	0	0	0	0	0	0
9	180	110	0	0	0	0	0
10	180	110	120	0	0	0	0
11	180	110	0	50	0	0	0
12	180	110	120	50	0	0	0
13	180	110	120	50	4.50	10	0
14	180	110	120	50	4.50	10	5

[1] Phosphate was applied seed placed by the farmer as 11-55-0. The levels applied were sufficient to supply 80 lb P_2O_5/acre at Cameron's, 60 lb P_2O_5/acre at Martyn's, and 105 lb P_2O_5/acre at Pederson's. In treatments 9 to 14, 11-55-0 was broadcast to supply an additional 110 lb of P_2O_5/acre.

[2] Nitrogen applications of greater than 60 lb/acre were applied as a split application. Sixty pounds was broadcast at seeding time and the rest in late June.

total dry matter (Table 1.3.3).

At the Martyn site very little yield response to any of the nutrient treatments was observed. This was to be expected since the soil test level of nitrogen was 111 lb NO_3-N/acre to 24 inches. One problem observed at this site was that the herbicide treatment applied by the farmer had damaged some of the plots, this added variability to the yield results and tended to obscure any nutrient response. At mid-season there was visually some response to nitrogen. At the Martyn site the overall yield of dry matter was quite good (between 5 and 6 tons/acre) and the yield of cob was also excellent showing a relatively advanced degree of maturity (average cob to total dry matter production ratio of .53). A trial set out on the Cameron site suffered from lack of water during the growing season as well as a weed problem. Also at this site there was a major difference in the crop from one end of the plot to the other. This difference appeared to be associated with a soil problem, however the nature of this problem was not apparent from the soil test results. At this site the yields were again quite variable within treatments and there was only slight indication of yield response to nitrogen at low application rates, although visual response was noted early in the season. The lack of maturity of the crop at the time of harvest is illustrated by the relatively low cob weights obtained from any of the treatments. At the Pederson site, the yields were again quite disappointing. At this site the crop suffered both from lack of water and also from a weed problem which was not effectively controlled. At this site the soil test level of nitrogen was low (27 lb NO_3-N/acre to 24 inches) and

Table 1.3.3 Yield results for corn.

Treatment Number	N Applied (lb/ac)	Other Nutrients	Dry Matter Yield					
			Cameron		Martyn		Pederson	
			Total lb/ac	Cob lb/ac	Total lb/ac	Cob lb/ac	Total lb/ac	Cob lb/ac
1	0	P	4105	288	10404	5426	4994	1825
2	30	P	7250	2449	11764	6210	4562	1457
3	60	P	7347	2017	10832	5349	5435	1961
4	90	P	7901	2185	10330	5138	5826	2272
5	120	P	6890	1897	11684	6194	6194	2449
6	180	P	4850	864	11924	6370	6178	2273
7	240	P	7589	3020	11764	6274	5302	1817
8	360	P	5930	1873	13188	7331	5074	2129
9	180	P	8019	1296	10980	6066	5282	2113
10	180	PK	7058	1753	11940	6210	5314	1809
11	180	PS	6410	1369	11188	5890	6608	2720
12	180	PKS	7923	2161	13044	6562	5666	1937
13	180	PKSZM	8091	2161	12228	6194	5320	2008
14	180	PKSZMC	6674	1753	13637	7106	5998	2215
Average (lb/ac)			6860	1800	11780	6201	5553	2069
Average Cob/Total Ratio				.26		.53		.37
Available Nitrogen expressed in lb/ac to the 2-foot depth			43		114		27	

there would appear to be a small response of the crop to applied nitrogen. Again, at this site the crop was not mature at the time of harvest so that the full yield potential was not realized. This again is reflected in the relatively low weight of cobs compared to the total dry matter weight.

Results of cob analyses for D.O.M. and nitrogen content are presented in Table 1.3.4. Values for both % digestible organic matter and % nitrogen are quite variable within each plot and the overall average values for each plot also differ. At the Cameron site, the average % D.O.M. was the highest and here there appears to be some trend in increasing % D.O.M. with increasing rates of nitrogen applied up to approximately 120 lb N/acre. At the Martyn site, % D.O.M. was at a maximum at the 60 lb applied N/acre rate while no trend was apparent on the Pederson site. The data on % nitrogen content gives no apparent consistent differences.

CONCLUSIONS

On the basis of results obtained this year, no comments can be made concerning the adequacy of the soil test recommendations for corn. While visual response was obtained to added nitrogen at all field trials, this response was not shown in the final yields measured. This reflects some of the problems associated with the corn crop, first obtaining a uniform stand and consequently a small sample representative of the crop yield, and secondly growing the crop to maturity in the season available for crop production in the Outlook area.

On the basis of this demonstration the major problems associated with corn production from the farmers' standpoint would appear to be obtaining earlier maturing varieties or

Table 1.3.4 Results of analyses of corn cobs from field experiments for D.O.M. and nitrogen content.

Treatment Number	N Applied (lb/ac)	Other Nutrients	Cameron		Martyn		Pederson	
			% DOM[1]	% N	% DOM	% N	% DOM	% N
1	0	P	51.3		57.7	1.16	65.9	1.30
2	30	P	57.4	1.21	63.8	1.27	66.4	1.50
3	60	P	65.7	1.44	65.3	1.14	57.8	1.46
4	90	P	63.7	1.11	61.3	1.25	62.9	1.41
5	120	P	66.2	1.42	59.8	1.25	64.9	1.40
6	180	P	60.2	1.37	57.8	1.38	57.5	1.60
7	240	P	61.5	1.37	59.1	1.22	59.8	1.46
8	360	P	63.2	1.39	58.0	1.33	57.4	1.58
9	180	add P			58.3	1.28	57.0	1.64
10	180	PK	59.7	1.42	58.4	1.22	56.3	1.71
11	180	PS	60.5	1.51	61.1	1.30	48.7	1.53
12	180	PKS	64.2	1.53	59.1	1.32	58.5	1.67
13	180	PKSZM	60.2	1.45	55.6	1.32	58.4	1.58
14	180	PKSZMC	61.3	1.56	54.9	1.30	56.9	1.32
Average			61.2	1.40	59.3	1.27	59.2	1.51

[1]% Digestible Organic Matter on an oven dry basis.

seeding present varieties earlier, and doing a better job of weed control and irrigation management.

One point that was evident this year is that in most cases the farmers did not apply irrigation water early enough or in sufficient quantities. Table 1.3.5 shows the average amount of moisture required by corn during the growing season for optimum production. These data clearly point out that corn requires substantial quantities of water during the period July 10 to August 20. It is during this period in particular that the amount of moisture supplied to the corn on both the Cameron and Pederson site fell considerably lower than that required by the crop. Even if it is assumed that both soils initially contained 4 inches of available water, by August 20 there was a deficit of at least 5 inches of moisture. To this date the corn on the Cameron site had not been irrigated and that on the Pederson site had received only one irrigation amounting to approximately 2 inches of water. Even with this irrigation the total amount of moisture supplied on the Pederson site was less than 6 inches. If it is again assumed that there was initially approximately 4 inches of available water in the soil at the Martyn site, it would then appear that there was adequate water for the growth of corn throughout the season, and by the 20th of August the amount of water required by corn approximately equalled the amount supplied. This probably is one of the major reasons why the Martyn corn plant substantially out-yielded the remaining two plots.

Table 1.3.5 Calculated consumptive moisture use of field corn[1] and amount of moisture supplied to corn in field experiments.

Time Period	Consumptive Moisture Use (inches)	Cumulative Consumptive Moisture Use (inches)	Cumulative Moisture Supplied in Field Experiments (inches)		
			Cameron	Martyn	Pederson
May 10-June 10	1.68	1.68	1.31	1.50	1.42
June 10-June 20	0.76	2.44	1.99	2.25	1.91
June 20-July 10	2.99	5.43	4.29	3.17	2.86
July 10-Aug. 1	4.01	9.44	4.96	6.90[3]	5.62[5]
Aug. 1-Aug. 20	5.28	14.72	5.08	10.97[4]	5.68
Aug. 20-Aug. 30	1.61	16.33			
Sept. 1-Sept. 20	2.11	18.44			

[1] Based on an average of 11 years data of L.G. Sonmor, CDA, Saskatoon.

[2] All moisture, except as noted, supplied by rainfall.

[3] Value includes approximately 3 inches irrigation water (July 6).

[4] Value includes approximately 4 inches irrigation water (Aug. 3).

[5] Value includes approximately 2 inches irrigation water (July 19).

1.4 Residual nitrogen at the end of the growing season

To determine the possibility of residual response to nitrogen in subsequent years and to determine the potential for downward movement of nitrate-nitrogen into the groundwater, a detailed full soil sampling program was conducted on the water control experiments. The optimum irrigation and dryland plots were sampled for the nitrogen treatment rates of 0, 100, and 300 lb N/acre. Two soil cores were removed from each replicate of these treatments for each crop. Samples of the eight cores from each nitrogen treatment for each crop were composited, air dried, and analyzed for nitrate-nitrogen content. Results are presented in Table 1.4.1.

The data indicate that little or no residual nitrogen in the nitrate form remained in the soil at either site following crop growth when rates up to 100 lb N/acre was applied. At the 300 lb applied N/acre rate varying amounts of residual nitrate remained in the soil. On the Asquith soil site both the dryland and optimum irrigation plots contained considerable quantities of residual nitrate. Here, most of the nitrate remaining in the optimum irrigation plots was located in the second foot, while under dryland conditions nitrate was concentrated in the top foot in the rapeseed plot and in the 6 to 24 inch depth in the barley and wheat plots. On the Elstow soil, the amounts of nitrate remaining in the optimum irrigation plots were relatively small and were concentrated in the second foot. The dryland rapeseed treatments contained very little residual nitrate, but the dryland barley and wheat contained relatively large amounts. This was

Table 1.4.1 Residual nitrate nitrogen levels from various rates of application of nitrogen for water control experiments.

Depth (in.)	N Applied (lb/acre)					
	Asquith Soil (Davison)			Elstow Soil (Anderson)		
	0	100	300	0	100	300
	Nitrate Nitrogen (lb/ac)					
	WHEAT (Optimum Irrigation)					
0-6	2	1	3	3	1	3
6-12	3	1	24	3	1	7
12-24	4	4	86	8	2	16
24-36	2	2	6	4	2	2
36-48	2	2	2	2	4	2
	WHEAT (Dryland)					
0-6	1	5	10	1	4	32
6-12	1	14	28	1	3	10
12-24	4	4	56	4	8	12
24-36	2	2	22	2	10	14
36-48	2	2	10	12	10	16
	BARLEY (Optimum Irrigation)					
0-6	7	6	13	7	7	
6-12	5	4	15	4	1	5
12-24	10	4	70	11	2	16
24-36	6	4	6	4	2	12
36-48	4	4	4	8	6	4
	BARLEY (Dryland)					
0-6	3	5	14	2	6	52
6-12	2	2	27	1	1	16
12-24	4	2	32	2	2	8
24-36	2	4	4	4	2	4
36-48	2	2	6	4	4	8
	RAPESEED (Optimum Irrigation)					
0-6	8	4	7		10	10
6-12	6	3	6	9	8	6
12-24	6	6	84	6	16	24
24-36	8	4	38	12	18	16
36-48	10	6	12	14	14	16
	RAPESEED (Dryland)					
0-6	5	8	33	3	12	13
6-12	4	5	22	4	4	6
12-24	6	8	6	8	8	8
24-36	10	12	6	8	14	16
36-48	10	12	10	14	10	6

concentrated in the top 6 inch to 1 foot depth. Results obtained this year are similar in many respects to those obtained in previous years except that in most cases nitrate nitrogen concentrations were found 6 inches deeper in the profile indicating greater movement had occurred.

1.5 Moisture requirements of irrigated crops

INTRODUCTION

This portion of the report summarizes the moisture conditions in the various research plots of the S.S.R.I.P. over the 1973 growing season. The objectives of the research program were:

1. To supply sufficient moisture to meet crop requirements,

2. To apply irrigation water in controlled amounts so that very little or none of the applied water was lost through deep percolation, and

3. To assess the importance of the irrigation water applied at various times through the growing season to determine whether any one of the water applications was more critical than another.

The appraoch taken in these studies where we controlled the irrigations was to maintain the moisture content of the soil at levels sufficient to supply the requirements of the growing crop. Moisture use by the crop was then approximated by the amount of water added to the soil minus water moving out of the profile by deep percolation. In the type C trials the irrigation system was controlled by the farmer and water was applied when he felt it was required. On these trials soil moisture levels were not monitored and moisture use by the crop is only very approximate.

EXPERIMENTAL METHODS

For the crops barley, soft wheat, and rapeseed, experiments where both fertility levels and moisture levels were controlled (referred to as type A experiments) were carried out on Elstow loam and Asquith very fine sandy loam soils. In the water 1 section of the type A experiments moisture levels were maintained at optimal or near optimal levels for plant growth. The way in which the soil moisture levels were maintained is outlined as follows.

Soil moisture levels were monitored by means of tensiometers installed at depths of 9 and 18 inches. The shallow tensiometers were used to obtain an indication of when to irrigate and the deep tensiometers provided information on the amount of water to apply. On both soil types, irrigation water was applied when the moisture tension in the shallow tensiometers reached a reading of 0.5 atmospheres. The amount of water to be applied was determined after consideration of the readings of the shallow and deep tensiometers, the storage properties of the soils, and the limitations of the sprinkler system within which amounts could be controlled. The approximate amounts applied are summarized in Table 1.5.1.

Table 1.5.1 Depth of water required to replenish soil moisture in water 1 trial.

Deep Tensiometer Reading	Depth of Water in Inches	
	Elstow Site	Asquith Site
0.3	2.5	1.5
0.3 - 0.7	3.5	
greater than 0.7	4.5	3.0

The water 3 trials were not irrigated (dryland controls) except for an initial irrigation of approximately 1 inch at the time of seeding to ensure germination.

Moisture levels are measured by sampling the 0-6 inch depth of the soil and determining moisture contents gravimetrically. Moisture contents at depths from 6-48 inches were determined at 6 inch moisture intervals by means of a neutron moisture meter. A detailed record of soil moisture levels was obtained from the water 1 plots, showing moisture levels before and after each irrigation. A somewhat less detailed record was also obtained for the water 3 plots.

To supplement this information it was decided to carry out a series of experiments where the crop was purposely stressed at various times during the growing season. This study, subsequently referred to as water 2, was carried out with a limited range of fertility treatments. It was carried out on the same soils and with the same crop varieties and herbicide treatments as the water 1 and water 3 trials. For each crop in a water 2 trial, the plot was divided into four sub-treatments designated A, B, C, and D.

Tensiometers and neutron access tubes were installed in each subplot of the water 2 treatment. When the average of the shallow tensiometer readings in the water 2 plot reached 0.5 atmospheres, the plot was irrigated. Sufficient water was applied to bring the amount of water applied to the water 2 treatment up to the total of irrigation plus precipitation received by the water 1 treatment. That is, the amount of irrigation water received or required by the water 1 treatment was also the amount applied to the water 2 treatment.

The subplots A, B, C, and D represent different stress treatments in the water 2 trial. At the first irrigation, subplot A received no water, the subplots B, C, and D received water up to the level received by the water 1 trial. At the second irrigation subplot B received no water, subplots A, C, and D were irrigated. At the third irrigation subplot C received no irrigation water, while subplots A, B, and D received water. Subplot D received irrigation at times indicated by tensiometers.

Detailed moisture records were kept on each subplot by gravimetrically determining the moisture contents of the 0-6 inch layers and determining soil moisture at depth with the neutron moisture meter.

For the type C experiments, where irrigation water was applied by the cooperating farmer, records were kept of rainfall and dates of irrigation. Where sprinkler irrigation was used, it was possible to measure the amount of water applied but where flood irrigation was used the amount of water applied is not known.

RESULTS AND DISCUSSION

Moisture and consumptive uses on the fertility studies

Irrigation water was applied to the plots in the type A experiments when the tensiometer readings indicated that water was required (when the average of the shallow tensiometer readings was 0.50 atmospheres). The amount of water applied was governed by the readings of the deep tensiometers and the soil properties (Table 1.5.1).

The amount of water applied to the water 1 plots are summarized in Table 1.5.2, along with the dates of water

Table 1.5.2 Amount of water applied to the Type A Water 1 plots and timing of Irrigation.

		Total Water Application Rainfall + Irrigation (inches)
	ELSTOW LOAM SOIL - ANDERSON SITE	
	Growing Season Rainfall 4.8"	
Barley	June 22, 3.1"; July 6, 3.4"; July 22, 3.6"	14.9
Soft Wheat	June 22, 3.0"; July 6, 2.3"; July 22, 3.4"	13.5
Rapeseed	June 26, 3.0"; July 11, 2.4"; July 24, 3.3"; Aug. 3, 2.5"	16.0
	ASQUITH VFSL SOIL - DAVISON SITE	
	Growing Season Rainfall 6.2"	
Barley	June 21, 2.3"; July 16, 3.0"	11.5
Soft Wheat	June 21, 2.2"; July 16, 3.0"	11.4
Rapeseed	June 27, 2.2"; July 16, 3.0"; Aug. 4, 2.1"	13.5

application. Two general trends are apparent from these data.

1. The amount of water applied to rapeseed was greater by approximately 2 inches than the amount applied to cereals. The reason for this difference appears to be that the rapeseed plots matured approximately 10 days later than either the barley or the soft wheat and the additional moisture was required, according to tensiometer readings, for this latter stage of growth.

2. The total moisture application at the Elstow site is about 2.5 inches greater than at the Asquith site. The main reason for this difference appears to be the additional rainfall

at the Asquith site at the end of June. This rainfall reduced the number of irrigations required by one at the Asquith site.

In Table 1.5.3 the amounts and timing of irrigations on the water 2 plots of the type A experiments are summarized. On the water 2 plots at the Elstow site a maximum of 3 irrigations were applied to all crops. Because of this, similar amounts of water are applied to all crops at this site. At the Asquith site the rapeseed plots received more irrigations and more water than the cereal plots. The water 3 plots on the type A experiments were dryland controls and the only water applied was precipitation, which totalled 4.8 inches on the Elstow site and 6.2 inches on the Asquith site.

In Table 1.5.4 the timing of irrigations on the type C plots are listed, as applied by the cooperating farmers. Where sprinkler systems were used an estimate of total moisture application is also made. In most cases the amount of irrigation water applied by the farmers was less than on the water 1 plots where irrigation was scheduled by tensiometers. Also, the number of irrigations was in most cases fewer than on the water 1 plots. Furthermore, in some cases the first irrigation by the farmers corresponded in timing with the second water application on the water 1 plots.

Crop moisture use can be estimated from daily records of pan evaporation and crop moisture use coefficients developed for the Outlook area[1]. Moisture use by the crop is calculated by multiplying the crop coefficient by the amount of pan evaporation.

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[1]Personal communication with Mr. L.G. Sonmor, Agriculture Canada Research Station, Saskatoon, Saskatchewan.

Table 1.5.3 Amounts and timing of irrigation applications in type A Water 2 experiments.

		Total Water Application Rainfall + Irrigation (inches)
	ELSTOW LOAM SOIL - ANDERSON SITE	
	Growing Season Rainfall 4.8"	
Soft Wheat		
A	July 11, 2.5"; July 24, 3.5"	10.8
B	June 26, 3.3"; July 24, 3.5"	11.6
C	June 26, 3.3"; July 11, 2.5"	10.6
D	June 26, 3.3"; July 11, 2.5"; July 24, 3.5"	14.1
Barley		
A	July 11, 2.7"; July 24, 3.9"	11.4
B	June 26, 3.7"; July 24, 3.9"	12.4
C	June 26, 3.7"; July 11, 2.7"	11.2
D	June 26, 3.7"; July 11, 2.7"; July 24, 3.9"	15.1
Rapeseed		
A	July 22, 4.1"; Aug. 3, 3.1"	12.0
B	July 3, 3.0"; Aug. 3, 3.1"	10.9
C	July 3, 3.0"; July 22, 4.1"	11.9
D	July 3, 3.0"; July 22, 4.1"; Aug. 3, 3.1"	15.0
	ASQUITH VFSL SOIL - DAVISON SITE	
	Growing Season Rainfall 6.2"	
Soft Wheat and Barley		
A	July 18, 3.1"	9.3
B	June 22, 2.9"	9.1
C and D	June 22, 2.9"; July 18, 3.1"	12.2
Rapeseed		
A	July 18, 3.2"; Aug. 3, 2.9"	12.3
B	June 27, 2.8"; Aug. 3, 2.9"	11.9
C	June 27, 2.8"; July 18, 3.2"	12.2
D	June 27, 2.8"; July 18, 3.2"; Aug. 3, 2.9"	15.2

Table 1.5.4 Estimated amounts of water applied to Type C plots and timing of Irrigation.

Name of Cooperator and Legal Location	Type of Crop	Type of Irrigation System	Growing Season Rainfall (inches)	Irrigation	Total Water Applied (inches)
A. Carlson	Soft wheat	Gravity	4.1	June 26; July 19	*
B. Niska	Soft wheat	Sprinkler	4.7	June 23, 4.0"; July 13, 26"	11.3
L. Pederson	Soft wheat	Sprinkler	4.2	June 20, 4.1"	8.3
A. Carlson	Barley	Gravity	3.4	July 7; July 22	*
L. Pederson	Barley	Sprinkler	4.4	June 22, 1.9"	6.3
A. Stranden	Barley	Gravity	3.9	June 26, July 17	*
A. Pederson	Rapeseed	Gravity	2.8	July 16	*
B. Niska	Rapeseed	Sprinkler	3.8	June 23, 1.7"; July 9, 2.8"	8.3
K. Carlson	Rapeseed	Sprinkler	4.4	July 1, 2.0"; July 18, 3.1"; Aug. 6, 3.3"	12.8

* Where gravity irrigation is used no estimate of amount of irrigation water is available.

One restriction on the technique as developed by Sonmor is that moisture use is calculated on the basis of average crop growth stages which are dictated by calendar dates. Because of this, in years when the growing season differs from the average, these moisture use estimates will be in error. The consumptive use estimates for 1973 calculated by this technique and the factors used in their calculation are listed in Table 1.5.5a.

To avoid using growth stages fixed on a calendar basis and to obtain somewhat more detail on moisture use patterns, a computer model was adapted to predict moisture levels on a daily basis throughout the growing season[1]. In this moisture budgeting program the crop growth stages are controlled by the accumulated growing degree days above 42°F during the growing season. Table 1.5.5b gives the estimated moisture use as calculated by this means as well as the factors used in the calculation.

On the type A experiments measurements were taken of the levels of soil moisture in the 0 to 4 foot depth throughout the growing season. This was done by means of gravimetric sampling of the 0-6 inch depth and measurements with a neutron moisture meter of the deeper depths. The crop moisture use can then be estimated from the equation:

$$WU = R + I + \Delta S \qquad (1)$$

where WU = water use

R = rain

I = irrigation

ΔS = change in soil moisture content.

---

[1]The Versatile Soil Moisture Estimator Program as developed by Wolfgang B. Baier, Research Branch, Plant Research Institute, Agriculture Canada, Ottawa, and modified by E. de Jong, Department of Soil Science, University of Saskatchewan was further modified and used for these calculations.

Table 1.5.5 Estimated crop moisture use and factors used in the calculation.

(a) SONMOR TECHNIQUE

Estimated Crop Moisture Use 1973

Cereals and rapeseed ------------------------------------ 15.5 inches

Factors Used in Calculations:

Ratio of Consumptive Use to Pan Evaporation	0.18	0.36	0.64	0.84	0.62	0.28
Date	May 10- May 31	June 1- June 10	June 11- June 30	July 1- July 31	Aug 1- Aug 10	Aug 11- Aug 30

(b) MOISTURE BUDGET TECHNIQUE

Estimated Crop Moisture Use 1973

Cereals --- 12.5 inches
Rapeseed -- 13.3 inches

Ratio of Consumptive Use to Pan Evaporation

Asquith Soil	0.16	0.34	0.47	0.66	0.68	0.50	0.18
Elstow Soil	0.16	0.28	0.44	0.68	0.65	0.45	0.18
Cumulative Growing Degree Days Above 42°F	0 - 227	228- 376	377- 752	753- 1466	1467- 1800	1801- 2122	2122-

The seasonal water use by the crops barley, soft wheat, and rapeseed on the type A plots as calculated from this equation are summarized in Table 1.5.6.

Table 1.5.6 Seasonal water use of barley, soft wheat and rapeseed on the type A plots.

Plot	Asquith 17/5 - Harvest Fertility Treatment				Elstow 24/5 - Harvest Fertility Treatment			
	1	4	6	Ave.	1	4	6	Ave.
BW1	11.0	12.6	13.0	12.2	10.9	10.5	15.2	12.2
BW3		11.4				9.0		
WW1	11.2	12.2	13.7	12.4	8.2	12.7	14.9	11.9
WW3		12.1				7.0		
RW1	13.3	15.0	16.7	15.0	11.8	13.1	13.6	12.8
RW3		12.4				7.4		
	Water Treatment				Water Treatment			
	A	B	C	D	A	B	C	D
BW2	12.6	13.0	15.6	14.6	7.1	10.9	12.2	12.3
WW2	13.2	12.5	15.6	15.1	6.8	8.7	11.2	10.8
RW2	16.7	15.3	15.5	17.8	9.8	10.4	12.0	12.6

B = Barley, R = Rapeseed, W = Wheat
W1, W2, W3 = three water levels
Plot 1 = 0 lb N/acre
Plot 4 = 75 lb N/acre
Plot 6 = 150 lb N/acre

For cereals on the water 1 plots the average moisture use is 12.3 inches. This figure is in good agreement with the moisture use figure as calculated from the moisture budgeting technique and somewhat lower than that estimated by the technique of L.G. Sonmor. As mentioned previously, the Sonmor technique will work well on an average growing season but not when the growth stages do not correspond to the fixed calendar dates. In 1973 the crop matured early in August and it appears likely that for this reason the Sonmor technique has overestimated the consumptive use.

It should be noted that on the Asquith site the moisture use on the water 3 plots was quite similar to that on the water 1 plots. This is reflected in the similarity of the crop yields of 36.6 bus/acre on the water 1 and 35.8 bus/acre on the water 3 plots for soft wheat and 53.7 and 43.1 bus/acre on the water 1 and water 3 plots respectively for barley. On the Elstow site there is a marked difference in the consumptive use between the water 1 and water 3 plots. This again is reflected in the crop yields of 55.4 bus/acre on water 1 and 31.4 bus/acre on water 3 for barley and 42.5 and 23.1 bus/acre on water 1 and water 3 respectively for soft wheat.

Also, on the water 1 plots it would appear that as the level of applied nitrogen is increased the moisture use also increases.

For rapeseed on the water 1 plots, moisture use as calculated from the measured values averaged 15.0 inches on the Asquith site and 12.8 inches on the Elstow site. The consumptive use figure of 15.0 inches on the Asquith site more closely corresponds to the figure calculated by the Sonmor technique for consumptive use. However, on examining the soil moisture data it is apparent that some of this increased moisture use is simply a reflection of moisture draining through the soil to below the 4 foot depth during the growing season. Thus it appears likely that the figure of 13.3 inches as calculated by the budgeting technique more accurately represents the consumptive use of water by the rapeseed crop on both the Asquith and Elstow locations.

With rapeseed, as with the cereals, it is apparent that at higher levels of applied nitrogen the moisture use is greater.

On the water 3 plots moisture use is lower than on the water 1 plots at both sites. Again this is reflected in markedly reduced yields of 13.1 and 2.3 bus/acre in the water 3 plots on Asquith and Elstow sites respectively compared to 33.0 and 33.2 bus/acre on the water 1 plots.

Irrigation Scheduling Studies - Soft Wheat, Barley and Rapeseed

The water 2 plots were divided into four subplots labelled A, B, C and D. Irrigation water was applied as required, determined by tensiometer readings. At the time of the first irrigation, subplot A received no water. The other three subplots received the required amount of irrigation water. At the time of the second irrigation, subplot B received no water, A, C, and D subplots received water; and at the time of the third irrigation subplot C received the required amount of irrigation water. In short then, A represents a plot receiving an early moisture stress, B represents a plot receiving a moisture stress part way through the growing season, and C represents a plot receiving a moisture stress late in the growing season. Subplot D received no moisture stress within the limits of our experiments. The exact details of timing and amounts of irrigation are summarized in Table 1.5.3.

The measured consumptive use of water by the crops as calculated from equation 1 is detailed in Table 1.5.6. The general trend shown by these data is that plots receiving a stress early in the growing season consumed less water than those receiving no stress or a stress late in the growing season.

On the Asquith site the consumptive use figures are two to five inches greater than on the Elstow site. On checking the soil moisture levels throughout the growing season it is apparent that one reason for this is that some of the water is draining directly through the profile to below the four foot depth.

The consumptive use figures again give a good indication of the crop yield. The yields of the three crops under the various irrigation regimes are reported in Table 1.5.7 and Figures 1.5.1, 1.5.2 and 1.5.3. Yields were determined for plots receiving 0, 100, 200, and a split application of 100 lbs of nitrogen/acre. The general trends shown in this experiment were that as the stress was applied later in the season or no stress at all was applied, the yields improved. This was true for all levels of fertility with the rapeseed crop and especially for fertilized treatments for soft wheat and barley.

Statistical analysis was carried out on these results to compare the various water sub-treatments. These result are summarized in Table 1.5.8. The overall conclusion which may be drawn from these results is that a moisture stress either early in the growing season or part way through it causes a marked reduction in the crop yield for all crops. This is especially true under conditions of high fertility.

The grain protein levels in soft wheat and barley did not show any consistent trends with changing irrigation schedules (Figure 1.5.4). Generally, the protein level in the crop receiving an early stress (water A) was higher than any of the other irrigation treatments. Also the protein levels in the

Table 1.5.7 Yields of soft wheat, barley, and rapeseed (bushels/acre) under various irrigation schedules (Water 2).

Applied Nitrogen lb/ac	Anderson Farm Schedule A	Schedule B	Schedule C	Schedule D	Davison Farm Schedule A	Schedule B	Schedule C	Schedule D
				SOFT WHEAT				
0	15.3	16.7	19.6	20.2	15.6	15.9	18.5	18.5
100	30.5	39.1	43.8	43.1	33.4	39.4	38.5	44.5
200	23.6	42.0	42.3	42.6	28.3	40.7	45.9	43.5
100 split[1]	28.5	30.4	33.1	36.5	28.9	37.4	41.3	40.2
				BARLEY				
0	21.7	23.7	29.0	32.7	28.6	26.4	30.9	30.7
100	52.6	45.5	57.8	54.8	41.5	50.5	65.0	65.0
200	53.6	55.8	60.3	65.2	48.0	61.5	75.2	70.6
100 split	44.1	47.6	51.3	60.4	37.4	57.3	59.7	56.6
				RAPESEED				
0	8.6	15.2	16.7	17.3	11.4	18.8	15.4	23.0
100	10.7	9.0	35.3	24.9	19.2	25.9	29.7	31.2
200	8.4	16.3	29.2	25.5	29.6	29.7	27.0	38.8
100 split	8.6	18.6	32.1	30.6	31.6	37.4	37.6	32.9

[1] In the split application, 50 lb/acre of nitrogen was applied broadcast at time of seeding and the remainder broadcast in late June.

BARLEY YIELDS

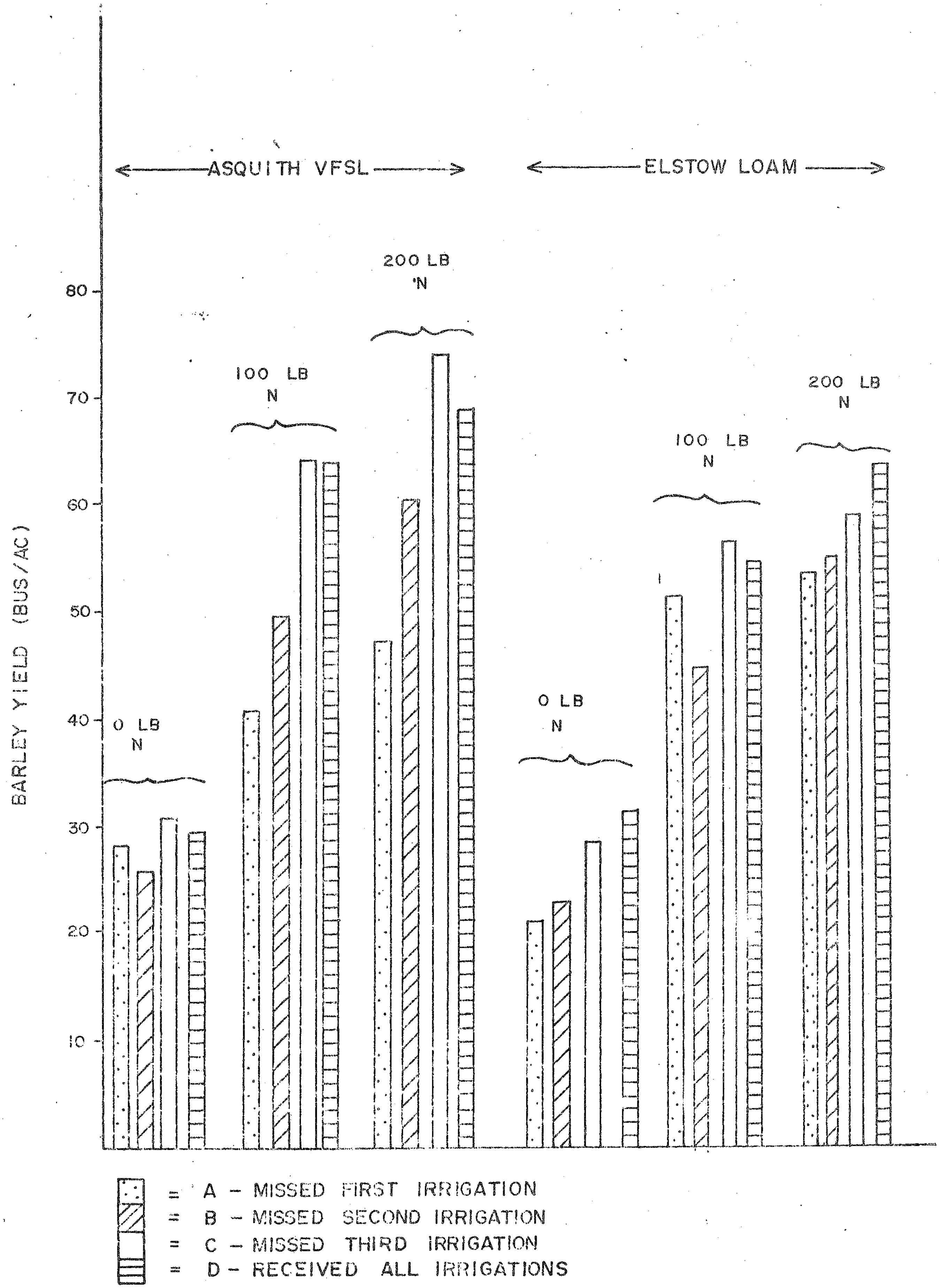


Fig. 15.1 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE YIELD OF BARLEY GROWN UNDER DIFFERENT RATES OF APPLIED NITROGEN

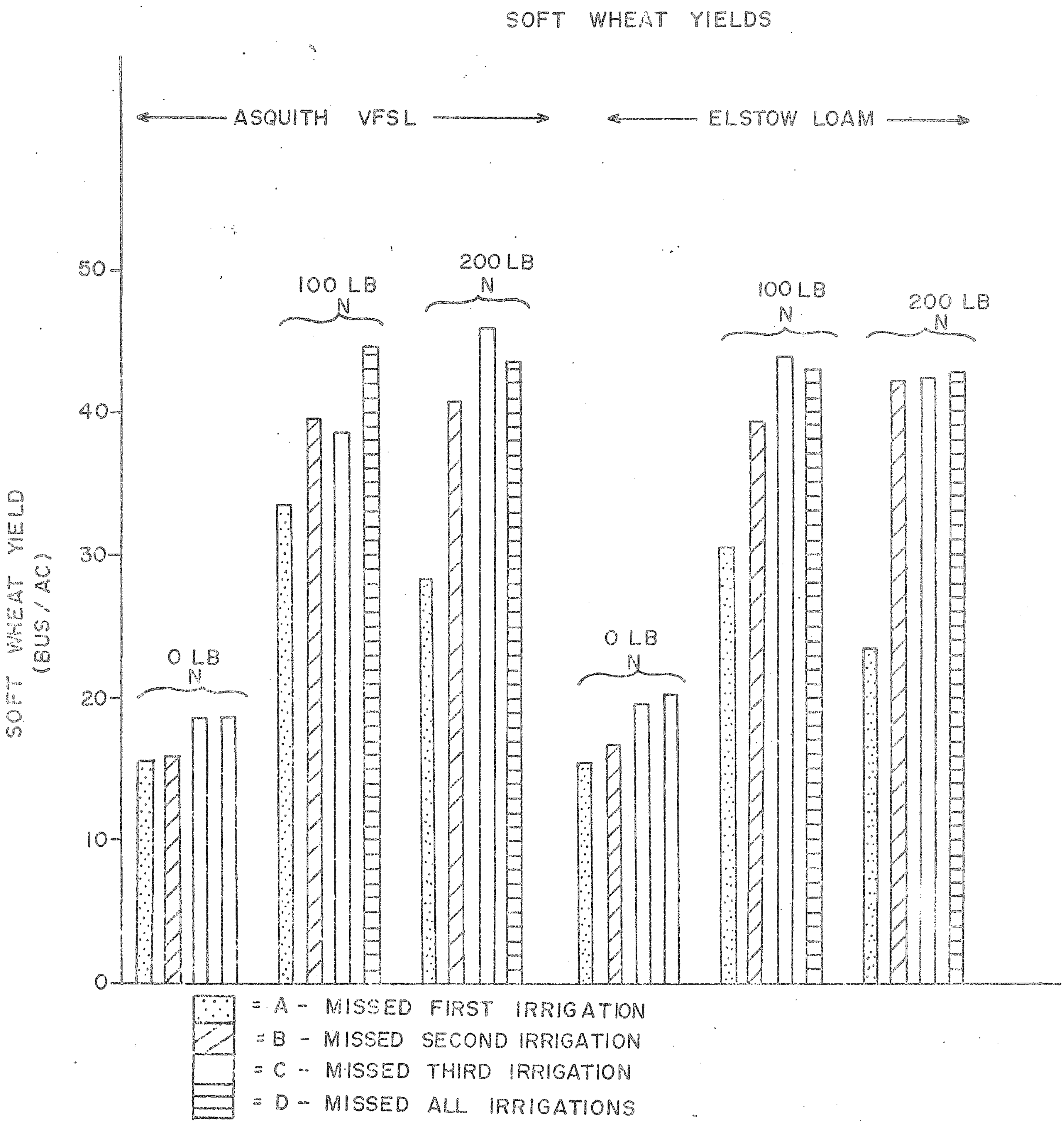


Fig 15.2 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE YIELDS OF SOFT WHEAT GROWN UNDER DIFFERENT RATES OF APPLIED NITROGEN

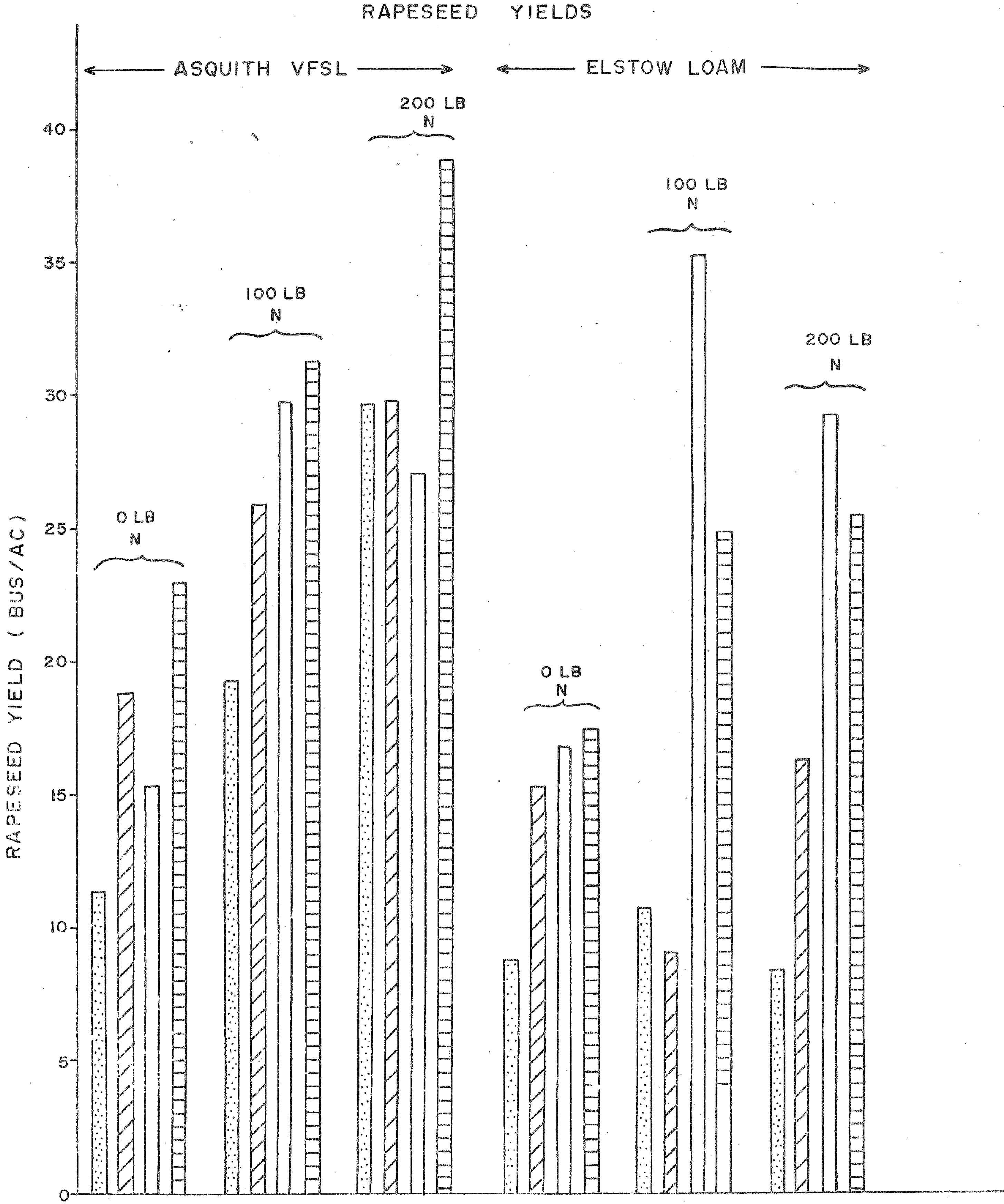


Fig 15.3 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE YIELD OF RAPESEED GROWN UNDER DIFFERENT RATES OF APPLIED NITROGEN

Table 1.5.8 Relative rating of yields from various irrigation regimes.

	ANDERSON SITE	DAVISON SITE
Soft wheat	A[1] <[2] B < C = D	A < B = C = D B < D
Barley	A = B < C = D	A < B < C = D
Rapeseed	A = B < C = D	A < B = C < D

[1] A subplot - missed the first irrigation
B subplot - missed the second irrigation
C subplot - missed the third irrigation
D subplot - received all irrigations

[2] The symbol < is read "yielded less than"
e.g. for B < C read subplot B yielded less than subplot C

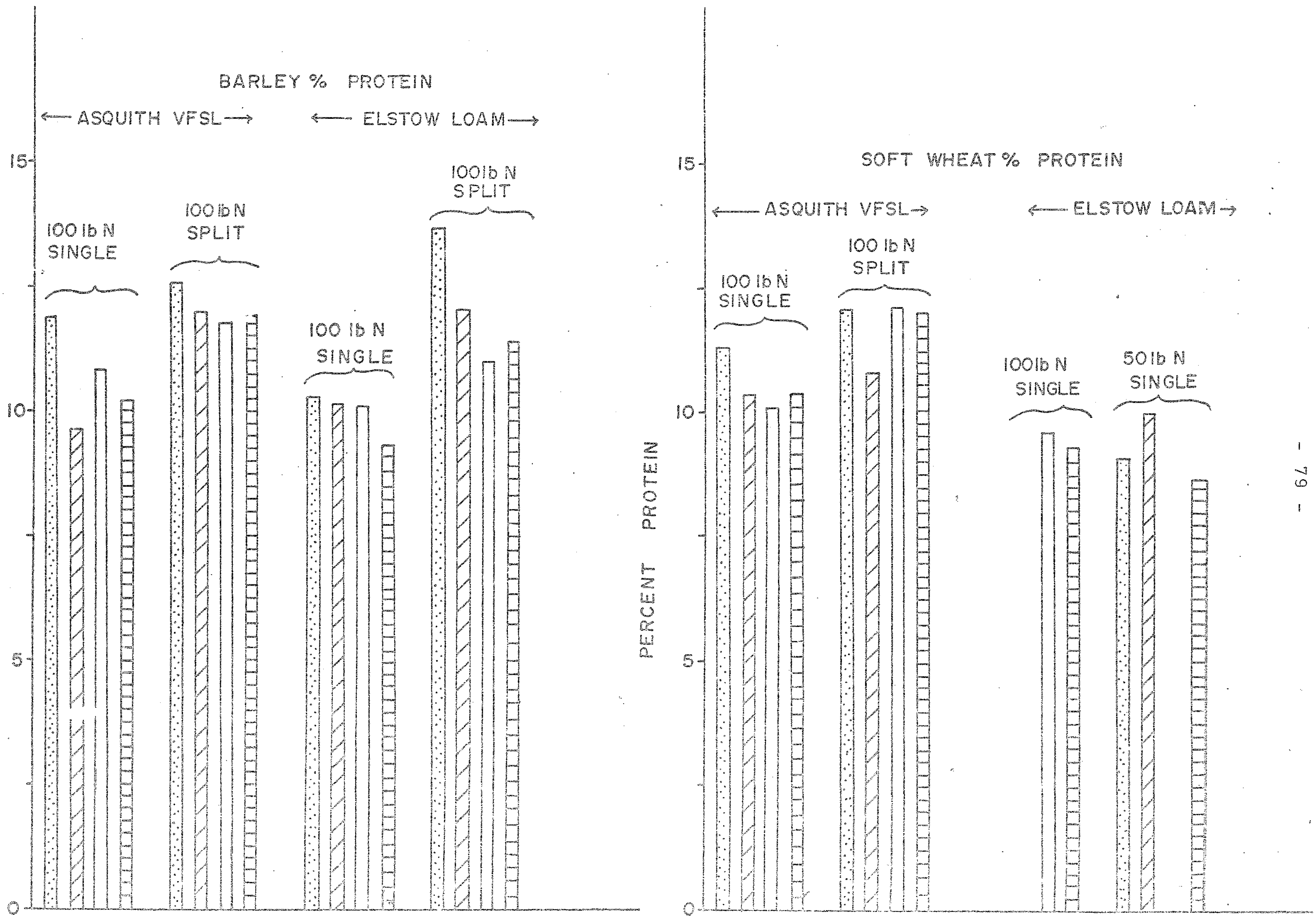


Fig.15.4 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE PROTEIN CONTENT OF BARLEY AND SOFT WHEAT

plots receiving a split nitrogen application were somewhat higher than those receiving a single application in the spring.

One of the objectives of this study was to minimize the amount of applied water which drained below the root zone and at the same time maintain sufficient moisture for good crop yields.

From the water 2 studies it would appear that on very light textured soils such as the Asquith site, some deep drainage is unavoidable. On the Elstow site, however, because the soil has a higher moisture storage capacity, irrigation can be carried out with minimal water loss due to deep drainage.

Efficient irrigation will be achieved by frequent applications of relatively small amounts of irrigation water. A further increase in the efficiency of the irrigation system can be achieved by restricting the final water application to a very small amount or else omitting it entirely. This latter procedure will of course be strongly dependent on the particular growing season. The results of the water 2 irrigation scheduling experiments suggest that the final irrigation has little effect on either the yield or the protein content of the crop. Furthermore, on the Elstow site on the water D sub-treatment, it was found that the soil moisture content was 3 inches greater in the zero to four foot depth at harvest time than at the first sampling in spring. On sub-treatment C there was 0.6 inches less water in zero to four foot soil profile at harvest than in the spring. This further suggests that the final irrigation was not used by the crop but rather that it remains in the soil and drains out below the rooting zone before the next crop is seeded.

On the Asquith site the moisture content of the zero to four foot profile was between 2.7 and 2.8 inches less at harvest than in the spring on both the C and the D sub-treatments. On the Asquith soil moisture storage is fairly low and it appears likely that deep drainge from the last irrigation will be relatively complete in both sub-treatments C and D prior to the moisture sampling at harvest time.

CONCLUSIONS

It must be emphasized that the results presented in this section are from one year's study. Before any definite recommendations can be made, this trial must be repeated for at least one more year and preferably two additional years.

1. Irrigation scheduling would appear to be quite important in achieving optimal yields of soft wheat, barley, and rapeseed. On the basis of one year's results, it would appear that stress early in the growing season and midway through the crop growth caused a greater yield reduction than did a stress somewhat later in the growing season. These results suggest that farmers who are willing to supply required levels of plant nutrients by fertilization should also pay close attention to their irrigation management practices.

2. Consumptive moisture use by the crops appears to increase with increasing levels of applied nitrogen.

3. The moisture budgeting technique appears to be an improvement over the Sonmor technique for calculating the moisture requirements and consumptive use of the various crops. Either technique is simple enough that it can be used to schedule irrigations during the growing season and could therefore assist farmers in achieving maximum production.

4. More efficient irrigation may be achieved in some growing seasons by reducing the amount of water applied in the final irrigation or omitting it entirely.

2. CROP UTILIZATION AND FATE OF FERTILIZER NITROGEN IN SOIL

INTRODUCTION

In 1972 a research project relating to nitrogen fertilization of stubble crops was initiated with the following objectives:

(1) to evaluate the response in terms of yield and quality of stubble seeded annual crops to two sources of nitrogen (urea and ammonium nitrate) applied in three fashions (broadcast, sidebanded, seed placed).

(2) to establish, through the use of ^{15}N enriched fertilizer, the relative efficiency of uptake by crops of different forms of nitrogen applied in the three methods, and to determine the fate of any nitrogen remaining in the soil following crop growth.

Results of the 1972 research was presented in the 1972 Soil Plant Nutrient Research Report. In 1973 a similar project was undertaken to gain further information to that obtained in 1972.

2.1 Response of barley and wheat to different sources and methods of application of fertilizer nitrogen

EXPERIMENTAL METHODS

In the spring of 1973, one site was selected for the establishment of a field trial. This was located on a stubble field of Blaine Lake silty clay loam soil (Peters farm). Adjacent areas were set aside for the establishment of barley and wheat plots. Composite soil samples were taken to a depth of four feet from both areas. Results of the analyses of these samples are presented in Table 2.1.1.

For both crops, small plots of the multi-rate, non replicated experimental design were set out. Bonanza barley and Neepawa

Table 2.1.1 Results of analyses of soils from areas selected for nitrogen trials.

Cooperator/ Location/ Crop	Soil Type/ Texture	Depth (in.)	NO_3-N	$NaHCO_3$ ext-P	$NaHCO_3$ ext-K	pH	Cond. mmho/cm
			lb/acre				
Peters	B:sicl	0-6	16	10	655	6.8	0.6
NW12-43-5-W3		6-12	8	4	260	6.7	0.3
		12-24	9	6	460	7.3	0.5
Barley		24-36	3	5	495	7.8	0.6
		36-48	8	3	500	7.8	1.0
Wheat	B:sicl	0-6	18	19	800	6.6	0.4
		6-12	10	7	300	6.6	0.3
		12-24	9	8	570	7.3	0.5
		24-36	4	4	590	7.9	0.6
		36-48	5	4	625	7.9	0.8

wheat were seeded. Phosphate as monoammonium phosphate (11-55-0) was applied with the seed to all treatments of both crops at a rate of 40 lb P_2O_5/acre. Nitrogen, as ammonium nitrate (34-0-0) and urea (46-0-0) was applied in separate treatments (broadcast, side banded, and seed placed). For all methods of placement, nitrogen was applied at rates of 10 to 90 lb N/acre in 5 pound increments and at additional rates of 100, 120, 150, 180 and 240 lb N/acre.

For the control of wild oats in barley, Avadex BW was applied preplant, and both barley and wheat plots received a post emergent wild oat spray in the form of Carbyne. Other post emergent herbicides used included Buctril M for both crops and I.C.A. for barley. Unfortunately, a heavy infestation of weeds was still encountered, particularly in the wheat plot where an annual grass species, Persian darnel, predominated. As a result, in late July, three square foot samples were harvested from selected treatments of both plots and weed and grain were separated, dried and weighed. This would allow for a measure of the effect that nitrogen fertilization has on weed growth and on the ability of the crops to compete with weeds.

At maturity, samples were harvested from all treatments, dried, threshed and weighed for yield estimations. Subsamples of both grain and straw were taken and ground for nitrogen analysis.

RESULTS

Response of Barley to Nitrogen Fertilization

Tables 2.1.2 to 2.1.4 present data obtained in the effect of applying urea and ammonium nitrate in three different methods

Table 2.1.2 The effect of broadcast urea and ammonium nitrate on the yield and nitrogen uptake of Bonanza barley.

	Ammonium Nitrate							Urea						
	Yield		Grain[1]	Straw[2]	N uptake lb/acre			Yield		Grain	Straw	N uptake lb/acre		
Applied lb/acre	Grain bu/ac	Straw lb/ac	Prot. %	N %	Grain	Straw	Total	Grain bu/ac	Straw lb/ac	Prot. %	N %	Grain	Straw	Total
0	47.6	2125	8.6	0.34	33.7	7.2	40.9	4.76	2125	8.6	0.34	33.7	7.2	40.9
10	48.1	2361						34.5	2010					
15	46.1	2625	8.3	0.39	32.1	8.5	40.6	36.9	1856	9.0	0.34	28.2	6.3	34.5
20	46.2	1573						42.6	1714					
25	43.3	2378						47.3	1947					
30	66.2	2794	9.0	0.23	46.1	8.5	54.6	77.3	3707	9.4	0.31	49.0	8.9	57.9
35	77.1	3931						65.5	2932					
40	69.5	3571						63.6	3286					
45	77.7	3647	9.8	0.28	57.8	9.8	67.6	57.4	2196	9.6	0.26	48.0	7.4	55.4
50	67.6	3274						61.3	3027					
55	65.6	3910						64.2	4115					
60	61.1	2246	10.1	0.32	52.9	9.1	62.0	81.9	4233	10.4	0.41	60.7	17.4	78.1
65	64.0	2395						66.4	4377					
70	61.3	3233						80.3	3957					
75	64.5		10.8	0.62	66.5	24.2	90.7	47.6	2583	10.3	0.32	56.1	10.7	66.8
80	98.6	4566						70.4	3465					
85	57.0	2887						54.0	2611					
90	76.8	3996	10.2	0.44	56.2	15.2	71.4	72.6	3684	10.8	0.39	56.3	8.2	64.5
100	76.1	3232	10.7	0.43	67.0	13.9	80.9	64.6	2746	10.1	0.33	53.7	9.1	62.8
120	68.4	2313	12.0	0.43	68.0	10.0	78.0	62.9	2952	12.3	0.52	63.7	15.4	79.1
160	84.7	3861	12.5	0.64	87.2	24.7	111.9	68.3	2948	11.2	0.42	63.0	12.4	75.4
180	71.7	3886	12.5	0.95	73.8	36.9	110.7	97.1	4966	13.2	0.67	105.5	33.3	138.8
240	109.3	4688	12.5	1.09	112.5	51.1	163.6	97.7	4982	13.1	0.81	105.4	40.4	145.8

[1] Grain protein based on % N at 13.5% moisture x 5.83.

[2] Straw % N on oven dry basis.

Table 2.1.3 The effect of sideband urea and ammonium nitrate on the yield and nitrogen uptake of Bonanza barley.

Nitrogen Applied lb/acre	Ammonium Nitrate: Yield Grain bu/ac	Yield Straw lb/ac	Grain Prot. %	Straw N %	N uptake lb/acre Grain	N uptake Straw	N uptake Total	Urea: Yield Grain bu/ac	Yield Straw lb/ac	Grain Prot. %	Straw N %	N uptake lb/acre Grain	N uptake Straw	N uptake Total
0	47.6	2125	8.6	0.34	33.7	7.2	40.9	47.6	2125	8.6	0.34	33.7	7.2	40.9
10	39.7	1744						34.6	1663					
15	44.7	1677	8.3	0.39	27.7	6.4	34.1	35.0	1773	8.5	0.27	25.3	4.8	30.1
20	37.3	1534						38.9	1934					
25	49.8	2823						33.8	1447					
30	61.8	2749	8.4	0.34	41.0	9.9	50.9	72.1	3447	9.1	0.36	43.9	10.1	54.0
35	66.4	3130						69.9	3545					
40	73.1	3759						83.7	4323					
45	64.2	3820	8.7	0.31	49.9	11.7	61.6	62.0	2517	9.9	0.29	58.8	10.3	69.2
50	71.6	3758						70.8	3837					
55	79.9	4330						77.8	4554					
60	57.0	2469	10.2	0.37	60.2	12.1	72.3	77.0	4611	9.4	0.37	63.9	16.9	80.8
65	78.3	3000						93.0	4499					
70	71.2	3308						92.1	4716					
75	62.8	3038	10.3	0.36	59.7	12.1	71.8	54.0	2771	9.8	0.35	62.4	13.9	76.3
80	77.2	3743						86.0	4406					
85	65.2	3161						73.8	3176					
90	81.5	3924	10.7	0.37	64.6	8.7	73.3	69.5	3125	10.5	0.38	61.9	12.0	73.9
100	80.9	3494	12.4	0.60	82.6	21.0	103.6	76.8	3230	11.3	0.46	71.5	14.9	86.4
120	72.7	2883	10.6	0.48	63.5	13.8	77.3	78.7	3581	11.7	0.43	75.8	14.7	90.5
160	73.8	3621	13.6	0.72	82.6	26.1	108.7	86.1	3686	11.7	0.61	82.9	22.5	105.4
180	85.4	3695	12.6	0.87	88.6	32.2	120.8	84.2	5738	12.9	0.65	89.4	37.3	126.7
240	84.3	3584	13.0	0.94	95.6	33.7	129.3	112.9	5371	12.7	1.09	118.1	58.5	176.6

Table 2.1.4 The effect of seed placed urea and ammonium nitrate on the yield and nitrogen uptake of Bonanza barley.

Nitrogen Applied	Ammonium Nitrate							Urea						
	Yield		Grain Prot.	Straw N	N uptake lb/acre			Yield		Grain Prot.	Straw N	N uptake lb/acre		
lb/acre	Grain bu/ac	Straw lb/ac	%	%	Grain	Straw	Total	Grain bu/ac	Straw lb/ac	%	%	Grain	Straw	Total
0	47.6	2125	8.6	0.34	33.7	7.2	40.9	47.6	2125	8.6	0.34	33.7	7.2	40.9
10	45.5	1765						37.3	1902					
15	54.0	2013	8.7	0.33	32.0	5.7	37.7	54.6	2537	9.0	0.27	31.4	5.6	37.0
20	34.6	1438						35.3	1791					
25	58.4	3239						46.2	1992					
30	54.3	2790	10.7	0.32	52.2	9.5	61.7	61.3	3190	9.6	0.29	47.0	8.2	55.2
35	65.0	2826						70.8	3271					
40	55.9	2693						80.3	3859					
45	64.6	3173	10.0	0.32	53.1	10.4	63.5	60.7	2435	16.1	0.32	58.5	10.0	68.5
50	72.9	3912						70.0	3101					
55	74.1	4133						94.9	4892					
60	51.9	2064	10.3	0.29	53.9	8.5	62.4	18.9	4190	11.1	0.32	79.2	14.5	93.7
65	59.8	2549						86.3	4535					
70	82.0	4156						86.2	4487					
75	78.6	3200	10.7	0.41	71.4	15.5	86.9	59.8	3223	10.3	0.48	61.8	18.1	79.9
80	82.5	3999						72.6	3621					
85	44.1	1773						57.6	2276					
90	69.9	3329	10.2	0.41	47.9	10.5	58.4	64.6	2711	9.9	0.40	49.8	10.0	59.8
100	89.4	4566	11.5	0.59	84.7	26.9	111.6	59.0	2563	10.9	0.62	53.0	15.9	68.8
120	58.4	2664	11.4	0.53	54.8	14.1	68.9	65.7	2929	9.7	0.62	52.5	18.2	70.6
160	77.2	3851	12.8	0.80	81.4	30.8	112.2	55.0	2532	11.6	0.73	52.5	18.5	71.0
180	72.1	4146	11.4	0.74	67.7	30.7	98.4	79.3	4138	11.2	0.78	73.1	32.3	105.4
240	84.4	4469	12.4	0.85	86.2	38.0	124.2	22.6	1836	11.8	1.11	22.0	20.4	42.4

on the yield and nitrogen uptake of barley. In all cases, reasonable yield responses were obtained with yields ranging from around 47 bu/acre in the check treatment to in excess of 80 bu/acre in treatments with higher rates of applied fertilizer nitrogen.

Curvillinear regression equations were derived based on the results obtained to describe the relationship between yields of barley and rate of nitrogen applied for each method of application of both curves. These equations are presented in Table 2.1.5 and the corresponding graphs are given in Figures 2.1.1 and 2.1.2.

Paired-T-tests were used to statistically compare the effects on barley yields of the different sources and method of fertilizer application. Results of these tests are presented in Table 2.1.6. Data indicates that for ammonium nitrate, there are no significant differences in yield between the various methods of application. Even at higher rates, yields of barley from the seed placement did not appear to be affected. This may have been due to the high amount of rainfall received shortly after seeding which removed much of the fertilizer from direct contact with the seed. In the case of urea, there is only one case where a significant different appeared. Yields from the side band application of urea were statistically larger than from the broadcast application with consistantly higher yields being obtained at most application rates greater than 30 lb N/acre. There were no statistical differences between the broadcast and seed placed application or between the side band and seed placed application, however at higher application rates (greater than 90 lb N/acre) the

Table 2.1.5 Relationship of barley yields to rate of nitrogen applied as affected by fertilizer source and methods of placement.

Fertilizer/ Method of Application	Regression Equation
NH_4NO_3-broadcast	$y = 41.1 + 806x - 6.7 \times 10^{-3}x^2 + 1.89 \times 10^{-5}x^3$
NH_4NO_3-side band	$y = 41.1 + .155x + 2.03 \times 10^{-2}x^3 - 3.46 \times 10^{-4}x^3 + 1.97 \times 10^{-6}x^4 - 3.68 \times 10^{-9}x^5$
NH_4NO_3-seed placed	$y = 44.8 + 6.35 \times 10^{-2}x + 1.56 \times 10^{-2}x^2 - 2.41 \times 10^{-4}x^3 + 1.28 \times 10^{-6}x^4 - 2.24 \times 10^{-9}x^5$
urea - broadcast	$y = 39.3 + .180x + 2.37 \times 10^{-2}x^2 - 4.66 \times 10^{-4}x^3 + 2.92 \times 10^{-6}x^4 - 5.79 \times 10^{-9}x^5$
urea - side band	$y = 29.8 + 1.31x - 1.16 \times 10^{-2}x^2 + 3.83 \times 10^{-5}x^3 - 2.84 \times 10^{-8}x^4$
urea - seed placed	$y = 41.1 - 8.15 \times 10^{-2}x + 4.30 \times 10^{-2}x^2 - 7.77 \times 10^{-4}x^3 + 4.69 \times 10^{-6}x^4 - 9.18 \times 10^{-9}x^5$

y = yield

x = rate of N applied

Fig. 2.1.1 The effect of ammonium nitrate on the yield of barley grown on Blaine Lake soil.

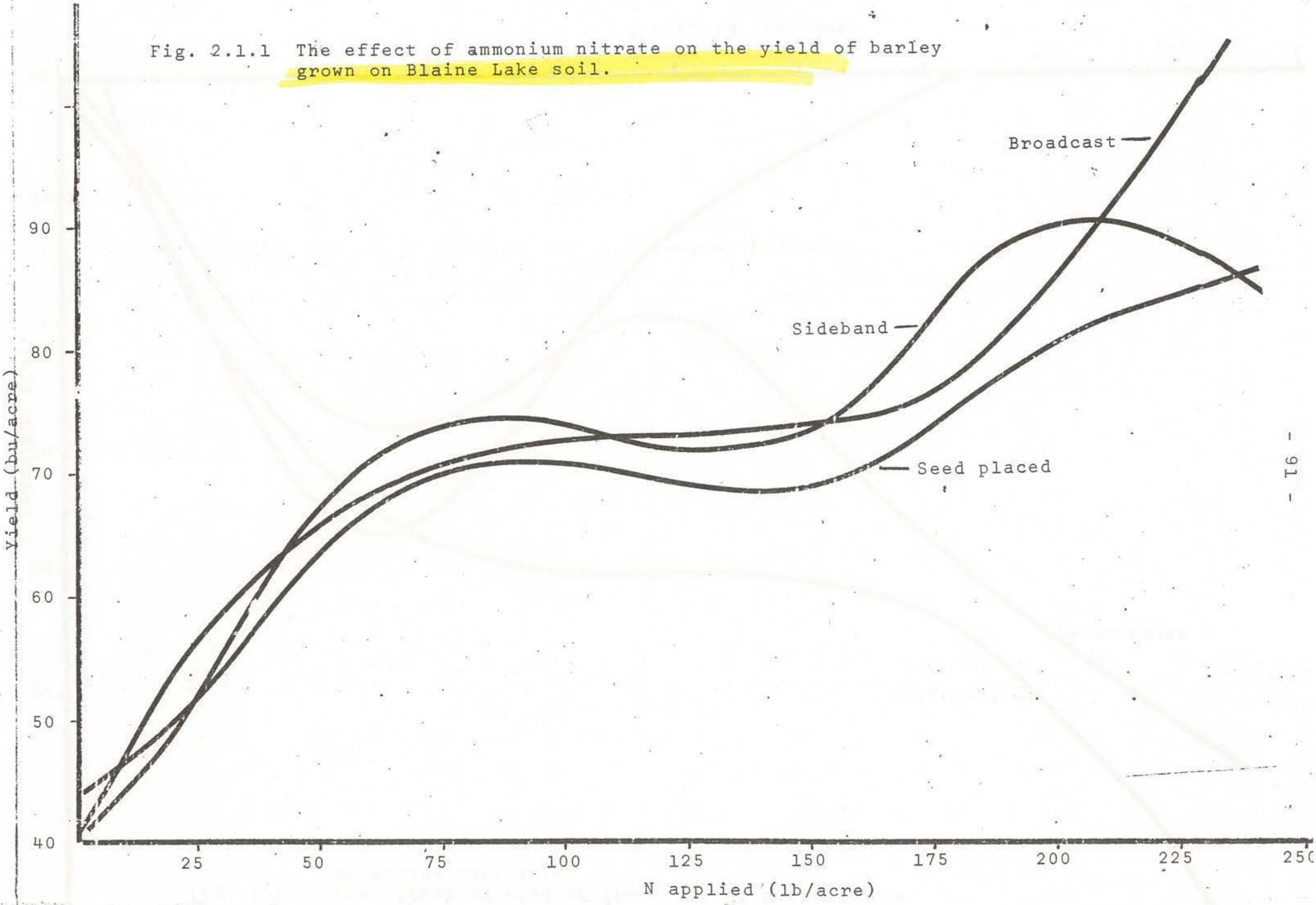


Fig. 2.1.2 The effect of urea on the yield of barley grown on Blaine Lake soil.

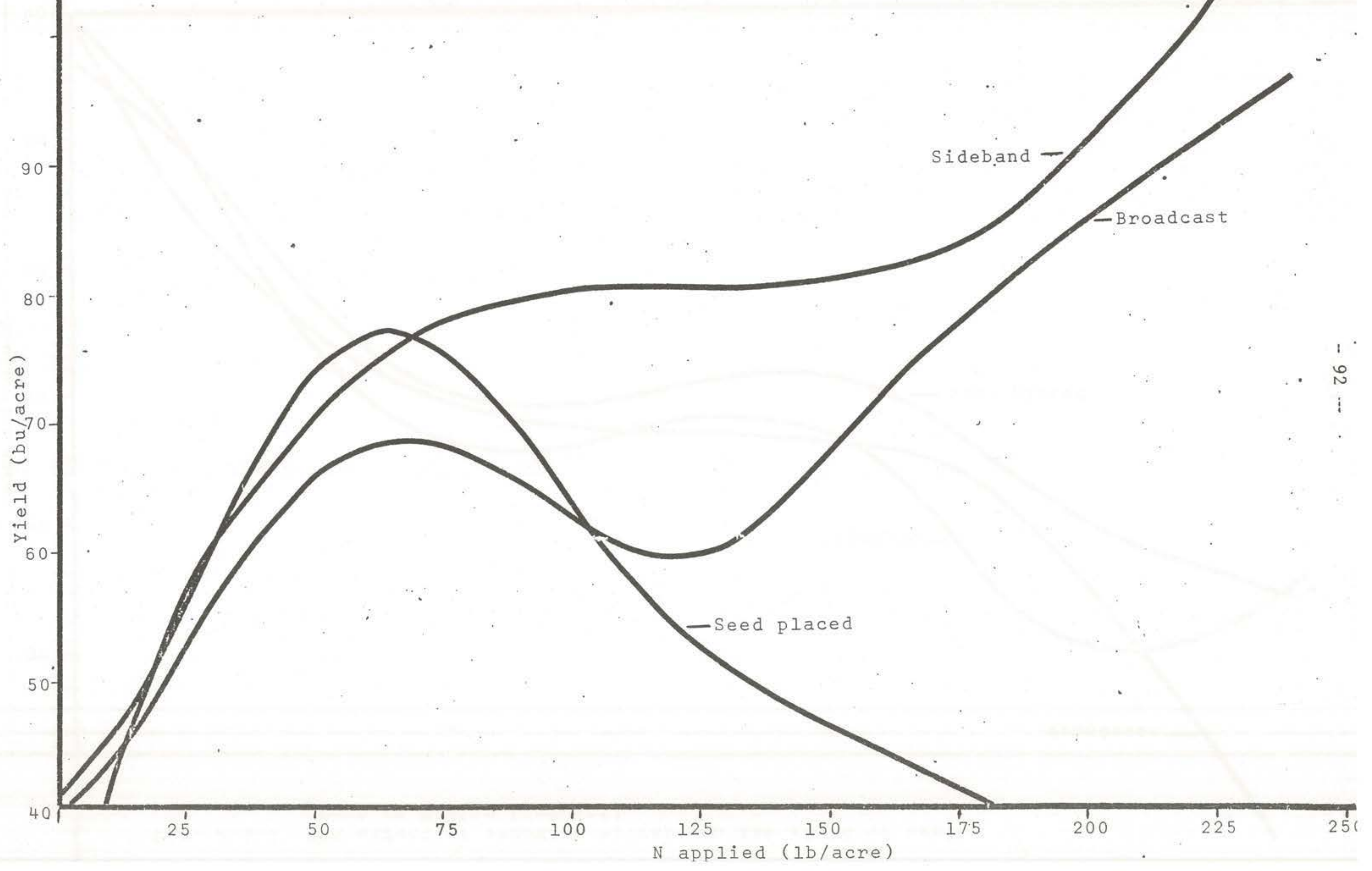


Table 2.1.6 Results of paired T-tests comparing the effect of different nitrogen sources and placements on yields of barley.

Comparison	T - value
A) NH_4NO_3	
broadcast vs side band	0.40 NS
broadcast vs seed placed	1.22 NS
side band vs seed placed	1.01 NS
B) Urea	
broadcast vs side band	2.99***
broadcast vs seed placed	0.02 NS
side band vs seed placed	1.42 NS
C) NH_4NO_3 vs Urea	
broadcast	1.35 NS
side band	1.68 NS
seed placed	0.14 NS

***Significantly different at 1%

NS - no significant difference

side band application appeared to give larger yields than the seed placement. Only at the highest application rate (240 lb N/acre) did there appear to be any serious effect of seed placement of urea. Again, this may be due in part to the high rainfall experienced immediately after seeding. A statistical comparison of two nitrogen carriers indicates that there were no significant differences between them.

Data on grain,protein and straw nitrogen contents indicate that, in general, these values increase with increased rates of fertilizer nitrogen applied. Marked increases in both of the values occur at high nitrogen application rates (around 100 lb N/acre). Corresponding to increases in yield along with grain, protein and straw nitrogen contents is a general increase in total nitrogen uptake by the crop.

Response of Wheat to Nitrogen Fertilization

Results pertaining to the yield and nitrogen uptake response of wheat to applied fertilizer nitrogen is presented in Tables 2.1.7 to 2.1.9. Reasonable yield responses to applied nitrogen were obtained with yields increasing from approximately 20 bu/acre in the check treatment to in excess of 40 bu/acre in higher nitrogen application rate treatments.

Regression equations relating yield of wheat obtained to rate of nitrogen applied for the two sources and three application methods are presented in Table 2.1.10, and graphical representations of these equations are presented in Figures 2.1.3 and 2.1.4. Results of paired T-tests are given in Table 2.1.11. The data obtained indicated that for the ammonium nitrate source, the side band application was slightly more effective in increasing

Table 2.1.7 The effect of broadcast urea and ammonium nitrate on the yield and nitrogen uptake of Neepawa wheat.

Nitrogen Applied lb/acre	Ammonium Nitrate: Yield Grain bu/ac	Yield Straw lb/ac	Grain Prot.[1] %	Straw[2] N %	N uptake lb/acre Grain	N uptake Straw	N uptake Total	Urea: Yield Grain bu/ac	Yield Straw lb/ac	Grain Prot. %	Straw N %	N uptake lb/acre Grain	N uptake Straw	N uptake Total
0	19.9	1752	9.9	0.29	22.2	5.0	27.2	19.9	1722	9.9	0.29	22.2	5.0	27.2
10	26.2	1826						32.2	2295					
15	13.7	1112	10.7	0.22	24.5	3.5	28.0	18.8	1257	16.1	0.29	23.7	4.4	28.1
20	21.0	1884						11.3	961					
25	13.1	1382						16.6	1696					
30	33.4	2691	9.7	0.27	28.9	5.9	34.8	31.5	2217	10.2	0.23	28.0	4.6	32.6
35	32.6	2461						25.0	2023					
40	28.1	2722						33.9	3263					
45	26.5	1932	10.3	0.26	33.9	6.3	40.1	29.0	2305	10.4	0.29	39.5	9.1	48.6
50	32.9	2564						38.2	3875					
55	40.1	3650						34.8	3416					
60	32.8	2410	10.4	0.36	43.7	9.5	53.2	40.1	2834	10.5	0.27	45.9	8.7	54.6
65	38.8	2860						41.4	3374					
70	42.3	2128						35.5	3731					
75	17.1	1441	11.5	0.38	30.2	8.2	38.4	7.4	600	10.5	0.36	29.8	8.5	38.3
80	33.7	2878						32.7	2741					
85	32.4	2744						14.4	1341					
90	44.1	3193	11.7	0.33	50.5	9.8	60.3	39.0	3589	11.6	0.41	34.9	10.1	45.0
100	37.2	2952	10.9	0.34	45.7	10.0	55.7	37.5	3534	12.1	0.50	51.2	17.7	68.9
120	29.8	2096	11.3	0.27	38.0	5.7	43.7	34.4	2047	11.7	0.41	45.4	8.4	53.8
160	44.6	3413	11.7	0.34	58.9	11.6	70.5	33.1	3190	13.3	0.57	49.7	17.9	67.5
180	41.4	5586	13.8	0.63	64.4	35.2	99.6	37.9	3059	12.8	0.60	54.7	18.4	73.1
240	44.8	3744	13.9	0.64	70.2	24.0	94.2	44.2	4341	13.6	0.75	67.8	32.6	100.4

[1] Grain protein based on %N at 13.5% moisture x 5.32

[2] Straw % N on oven dry basis.

Table 2.1.8 The effect of sideband urea and ammonium nitrate on the yield and nitrogen uptake of Neepawa wheat.

Nitrogen Applied lb/acre	Ammonium Nitrate: Yield Grain bu/ac	Ammonium Nitrate: Yield Straw lb/ac	Ammonium Nitrate: Grain Prot. %	Ammonium Nitrate: Straw N %	Ammonium Nitrate: N uptake lb/acre Grain	Ammonium Nitrate: N uptake lb/acre Straw	Ammonium Nitrate: N uptake lb/acre Total	Urea: Yield Grain bu/ac	Urea: Yield Straw lb/ac	Urea: Grain Prot. %	Urea: Straw N %	Urea: N uptake lb/acre Grain	Urea: N uptake lb/acre Straw	Urea: N uptake lb/acre Total
0	19.9	1722	9.9	0.29	22.2	5.0	27.2	19.9	1722	9.9	0.29	22.2	5.0	27.2
10	22.4	1603						31.5	2239					
15	17.5	1354	9.7	0.29	21.0	4.2	25.2	9.9	803	10.1	0.29	22.6	4.4	27.0
20	17.8	1688						18.0	1476					
25	53.3	2663						29.6	2716					
30	34.2	2952	9.5	0.27	39.4	8.3	47.6	38.6	3036	9.6	0.30	40.5	9.3	49.8
35	42.7	3564						43.9	3508					
40	40.3	3624						38.1	3046					
45	32.0	2272	10.3	0.27	44.7	8.5	53.2	36.8	3065	10.7	0.30	50.9	10.6	61.5
50	43.2	3576						51.6	4463					
55	43.8	3679						31.3	3288					
60	37.6	2759	10.3	0.31	43.5	10.2	53.7	46.1	3532	11.8	0.30	54.9	10.9	65.8
65	36.0	3382						46.4	4042					
70	40.5	4205						39.0	3850					
75	26.2	2196	11.6	0.27	48.8	9.5	58.3	21.4	1367	11.2	0.36	41.9	8.5	50.4
80	45.2	4145						39.0	2953					
85	25.2	2510						53.0	2390					
90	34.0	2346	10.6	0.25	35.4	6.1	4.5	34.9	2896	11.0	0.29	54.5	8.0	62.5
100	38.1	2754	10.6	0.32	45.6	8.8	54.4	39.9	3001	11.4	0.28	51.3	8.4	59.7
120	29.9	2217	10.4	0.27	35.1	6.0	41.1	31.5	2082	10.5	0.29	37.3	6.0	43.3
160	42.1	3372	13.9	0.48	66.0	16.2	82.0	37.6	3139	13.9	0.54	59.0	17.0	76.0
180	48.1	4903	13.9	0.81	75.4	39.7	115.1	48.9	4269	13.8	0.70	76.1	29.9	106.0
240	42.9	4234	13.9	0.70	67.3	29.6	98.9	50.8	5685	13.5	0.82	77.4	46.6	124.0

Table 2.1.9 The effect of seed placed urea and ammonium nitrate on the yield and nitrogen uptake of Neepawa wheat.

Nitrogen Applied lb/acre	Ammonium Nitrate: Yield Grain bu/ac	Yield Straw lb/ac	Grain Prot. %	Straw N %	N uptake lb/acre Grain	N uptake Straw	N uptake Total	Urea: Yield Grain bu/ac	Yield Straw lb/ac	Grain Prot. %	Straw N %	N uptake lb/acre Grain	N uptake Straw	N uptake Total
0	19.9	1722	9.9	0.29	22.2	5.0	27.2	19.9	1722	9.9	0.29	22.2	5.0	27.2
10	27.5	1905						32.2	2903					
15	14.3	1150	9.2	0.24	20.8	3.6	24.4	21.9	1459	9.5	0.22	24.5	3.9	28.4
20	18.3	1461						14.4	989					
25	26.5	2207						20.7	1939					
30	27.2	2544	9.9	0.27	34.1	7.2	41.3	37.3	2877	10.1	0.31	35.5	8.4	43.9
35	37.9	3245						35.5	3290					
40	28.1	2700						42.9	3521					
45	14.8	1075	10.1	0.28	31.0	6.5	37.5	23.8	1933	10.5	0.28	41.6	8.4	50.0
50	38.8	3177						38.7	3592					
55	44.8	3494						34.7	3738					
60	30.9	2241	10.3	0.29	41.2	7.7	48.9	30.6	2489	10.3	0.25	37.8	7.4	45.2
65	30.7	2172						32.2	2691					
70	45.5	4460						39.8	3410					
75	31.2	2463	10.6	0.31	48.5	11.3	59.8	19.2	1133	10.4	0.29	36.2	7.4	43.6
80	44.9	3704						33.6	3123					
85	27.8	2380						25.9	1868					
90	48.1	3457	11.4	0.31	48.8	9.1	57.8	29.5	2562	12.0	0.39	37.5	8.6	46.1
100	46.4	3576	11.7	0.39	61.2	14.0	75.2	35.5	3052	11.2	0.39	44.8	11.9	56.7
120	38.1	3316	10.9	0.29	46.8	9.6	56.4	20.5	1409	12.4	0.46	28.7	6.5	35.2
160	46.2	3665	13.3	0.48	69.3	17.6	86.9	25.1	2447	11.9	0.46	33.7	11.3	45.0
180	43.6	4900	13.5	0.67	66.4	32.8	99.2	30.1	3040	12.7	0.58	43.1	17.6	60.7
240	42.7	3741	14.6	0.72	70.3	26.9	97.2	40.6	4511	13.5	0.76	61.8	34.3	96.1

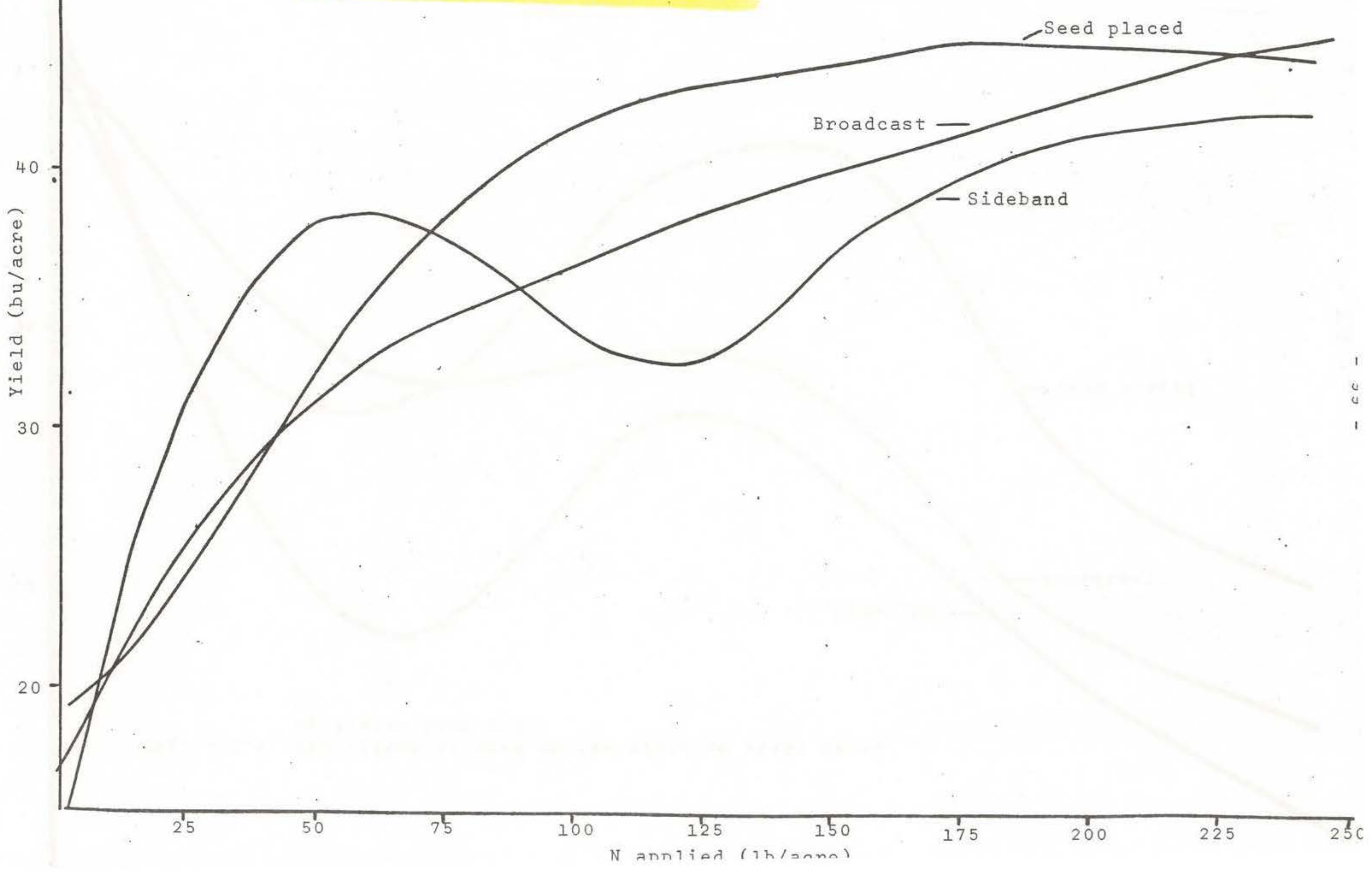
Table 2.1.10 Relationship of wheat yields to rate of nitrogen applied as affected by fertilizer source and method of application.

Fertilizer/ Method of Application	Regression Equation
NH_4NO_3-broadcast	$y = 16.3 + .453x - 3.96 \times 10^{-3}x^2 + 1.75 \times 10^{-5}x^3 - 2.82 \times 10^{-8}x^4$
NH_4NO_3-side band	$y = 14.8 + .789x - 4.88 \times 10^{-3}x^2 - 7.17 \times 10^{-5}x^3 + 7.83 \times 10^{-7}x^4 - 1.87 \times 10^{-9}x^5$
NH_4NO_3-seed placed	$y = 19.8 + 2.15 \times 10^{-2}x + 9.17 \times 10^{-3}x^2 - 1.19 \times 10^{-4}x^3 + 5.72 \times 10^{-7}x^4 - 9.47 \times 10^{-10}x^5$
Urea - broadcast	$y = 19.3 + .171x + 4.77 \times 10^{-3}x^2 - 1.06 \times 10^{-4}x^3 + 6.62 \times 10^{-7}x^4 - 1.28 \times 10^{-9}x^5$
Urea - side band	$y = 17.5 + .407x + 9.37 \times 10^{-3}x^2 - 2.43 \times 10^{-4}x^3 + 1.59 \times 10^{-6}x^4 - 3.19 \times 10^{-9}x^5$
Urea - seed placed	$y = 19.9 + .350x + 2.13 \times 10^{-3}x^2 - 1.13 \times 10^{-4}x^3 + 8.02 \times 10^{-}x^4 - 1.62 \times 10^{-9}x^5$

y = yield

x = rate of nitrogen applied

Fig. 2.1.3 The effect of ammonium nitrate on the yield of wheat grown on Blaine Lake soil.



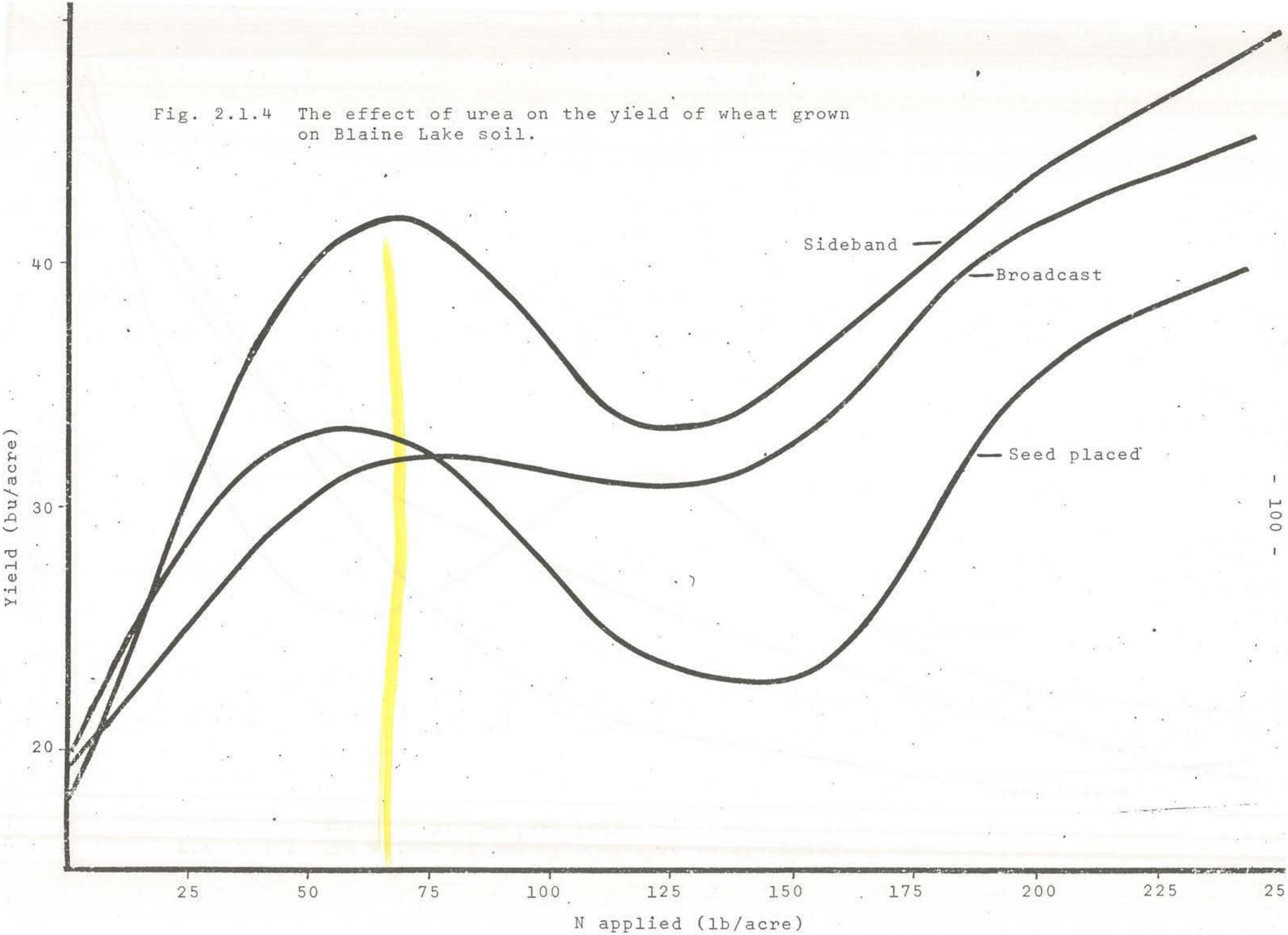


Fig. 2.1.4 The effect of urea on the yield of wheat grown on Blaine Lake soil.

Table 2.1.11 Results of paired T-tests comparing the effects of different nitrogen sources and placements on the yield of wheat.

Comparison	T - value
NH_4NO_3	
broadcast vs side band	1.87*
broadcast vs seed placed	1.52 NS
side band vs seed placed	0.58 NS
Urea	
broadcast vs side band	2.93***
broadcast vs seed placed	1.04 NS
side band vs seed placed	3.54***
NH_4NO_3 vs Urea	
broadcast	1.18
side band	0.74
seed placed	1.96*

*Significantly different at 10%

***Significantly different at 1%

NS - No significant difference

wheat yields than was broadcasting, particularly at rates lower than 60 lb applied N/acre. There, however, appeared to be no difference between side banding and seed placement or broadcasting and seed placement. As was the case in the barley trial, there again appeared to be no detrimental effect of applying high rates of ammonium nitrate with the seed. For urea, side banding appeared to be the most effective method of applying this carrier. Yields were statistically greater from this method of application than from either broadcasting or seed placement. There was no statistical difference in yields from these latter two methods of applying urea, however, at rates up to 40 lb applied N/acre seed placement appeared to be more effective, while at rates greater than 90 lb applied N/acre broadcasting appeared to be superior. There may have been some toxic effects of seed placed urea at rates in excess of 100 lb N applied/acre. However, these effects were not as dramatic as would have been expected. A comparison of the two carriers indicated that similar yields were obtained from both urea and ammonium nitrate when broadcast and side banded. However in seed placement, yield from ammonium nitrate were statistically greater than from urea. This was particularly apparent at nitrogen application rates in excess of 65 lb N/acre.

Similar to the results from the barley plot, the grain protein and straw nitrogen content of wheat generally increased with increased rates of fertilizer nitrogen applied, with large increases occurring around 100lb applied N/acre. Total plant nitrogen uptake also increased with rate of fertilizer nitrogen applied.

Relationship Between Nitrogen Fertilization, Crop Growth and Weed Growth

Due to a heavy infestation of darnel on both the barley and wheat plots, for which there is no herbicide control available, it was decided in mid-July to obtain samples from selected treatments and determine whether any relationship existed between rate of nitrogen applied, weed growth and crop growth. Samples representing a three square foot area were cut at ground level from odd numbered treatments of broadcast and seed placed urea and ammonium nitrate plots from both crops. Weeds and crop were separated, dried and weighed. Results are presented in Table 2.1.12 for the barley plot and Table 2.1.13 for the wheat plot.

Data clearly indicate that weeds were much more a problem on the wheat plot. The overall weight of weeds were greater on the wheat plot than on the barley plot, while the weight of crop was lower. Hence, the crop to weed ratio was much lower on the wheat plot. An overall average indicates an almost equal weight of crop and weeds were encountered on the wheat plot, while the crop weight on the barley plot was almost four times the weed weight. The major difference in herbicidal application was that the barley plot received preplant Avadex and post emergent T.C.A. Since wild oats were not a major problem, the difference was not due to the Avadex applied in barley. T.C.A. appeared to give some control of green foxtail in barley which could not be applied to wheat; however, the main weed encountered in the wheat which was not as prevalent in barley was Persian darnel. T.C.A. may

Table 2.1.12 Weight of crop and weeds encountered on selected treatments of barley plot.

Rate of N Applied (lb/acre)	Barley Weight (gm/3 ft^2) Ammonium Nitrate Broadcast	Ammonium Nitrate Sideband	Urea Broadcast	Urea Sideband	Weed Weight (gm/3 ft^2) Ammonium Nitrate Broadcast	Ammonium Nitrate Sideband	Urea Broadcast	Urea Sideband	Average Barley Weight	Average Weed Weight	Average Crop/Weed Weight
0	98.8	113.8	124.8	87.4	23.1	30.3	32.0	31.8	106.2	29.3	3.6
15	89.8	139.1	64.0	91.6	39.2	16.6	32.0	33.8	94.9	30.4	3.1
25	132.9	141.0	143.8	116.1	46.7	76.4	53.6	32.0	133.5	52.2	2.6
35	167.2	146.3	152.1	162.9	35.1	25.2	41.2	21.3	157.1	30.7	5.0
45	157.8	138.3	110.4	109.4	40.1	33.3	58.8	58.5	129.0	47.7	2.7
55	158.5	154.6	137.1	140.8	28.6	10.5	52.4	15.6	147.8	26.8	5.6
65	156.1	158.2	139.4	148.1	40.4	42.8	44.0	53.0	150.5	45.1	3.3
75	144.4	140.2	134.8	110.1	27.1	26.7	61.9	41.4	132.8	39.3	3.3
85	153.2	120.8	118.2	101.6	48.2	48.3	116.9	102.6	123.5	79.0	1.6
110	144.2	169.8	149.8	107.6	47.6	15.4	19.1	57.4	142.9	34.9	4.2
150	198.2	149.3	193.7	150.5	35.3	22.7	38.0	56.3	172.9	38.1	4.6
240	187.2	192.4	232.5	69.5	23.4	14.8	9.1	53.5	170.4	25.2	6.7
Average	149.0	147.0	141.7	116.3	36.2	30.3	46.6	46.4	138.5	39.9	3.9

Table 2.1.13 Weight of crop and weeds encountered on selected treatments of barley plot.

Rate of N Applied (lb/acre)	Barley Weight (gm/3 ft^2)				Weed Weight (gm/3 ft^2)				Average Barley Weight	Average Weed Weight	Average Crop/Weed Weight
	Ammonium Nitrate		Urea		Ammonium Nitrate		Urea				
	Broadcast	Sideband	Broadcast	Sideband	Broadcast	Sideband	Broadcast	Sideband			
0	45.2	33.2	51.6	73.0	78.0	40.8	71.5	43.4	50.8	58.4	0.87
15	41.9	54.3	28.5	30.2	40.1	47.8	72.2	80.7	38.7	60.2	0.64
25	39.3	71.5	57.6	95.0	128.4	80.1	63.8	58.5	65.9	82.7	0.80
35	81.5	104.0	104.7	107.0	67.0	50.0	61.8	44.0	99.3	55.7	1.78
45	90.4	70.1	55.4	75.2	125.3	49.6	93.6	70.4	72.8	84.7	0.86
55	94.6	111.0	107.5	113.2	74.5	51.4	55.4	61.8	106.6	60.8	1.75
65	95.0	60.5	95.8	126.5	63.6	92.0	102.9	59.6	94.5	79.5	1.19
75	104.4	97.4	44.9	50.1	54.4	71.3	91.7	82.7	74.2	75.0	0.99
85	93.9	68.5	72.7	58.9	95.5	99.0	98.3	110.0	73.5	100.7	0.73
110	61.6	116.5	89.2	79.8	102.5	65.2	75.0	98.7	86.9	85.3	1.02
150	98.1	113.6	87.6	65.5	82.8	89.2	86.7	89.5	91.2	87.1	1.05
240	129.6	111.2	109.3	58.3	72.3	85.3	52.9	82.8	102.1	73.3	1.39
Average	81.3	84.3	75.0	77.7	82.0	68.5	77.2	73.5	79.7	75.3	1.09

possibly have given some control of the weed in barley, although it is not a recommended chemical for use in its control.

There appears to be no indication of differences in weed or crop weights due to either source or placement of nitrogen; however, increasing rates of nitrogen appear, particularly in barley, to cause a greater increase in crop weight over weed weight.

CONCLUSIONS

On the basis of results obtained from the experiment conducted in 1973, the following conclusions can be drawn:

(1) The broadcast, side band and seed placed applications of ammonium nitrate appeared to be equally effective for barley and wheat.

(2) Side banding of urea appeared to give greater yields of barley and wheat than did either broadcasting or seed placement. At higher application rates seed placement of urea was the least effective method of application.

(3) Urea and ammonium nitrate were equally effective when broadcast and side band applied to barley and wheat; but at higher application rates, seed placed ammonium nitrate gave higher yields of wheat than seed placed urea.

2.2 Fate of fertilizer nitrogen

In the preceding section, data have been presented dealing with the yield response of barley and wheat to broadcast, side banded and seed placed urea and ammonium nitrate. A second important aspect of this study was to measure in detail the relative efficiency of uptake by crops of nitrogen from these different sources and methods of placement and to determine the fate of any nitrogen remaining within the soil following crop growth. This was facilitated through the use of ^{15}N enriched fertilizer materials.

EXPERIMENTAL METHODS

Within both the barley and wheat plots, small subplot areas were set aside for "nitrogen utilization" studies and, adjacent to the barley plot a second subplot area was set out for "nitrogen balance" studies.

The "nitrogen utilization" studies involved the application in six individual non-replicated treatments, for each crop, of ^{15}N labelled urea and ammonium nitrate. Both carriers were broadcast, side banded and seed placed at a rate of 30 lb N/acre. The degree of labelling for each carrier was approximately 1% excess ^{15}N, with both ions of the ammonium nitrate being tagged. This degree of labelling would allow for a measure to be made of the relative efficiency of fertilizer nitrogen uptake by the crops from the two sources and three methods of application.

The "nitrogen balance" studies conducted with barley contained nine non-replicated treatments. The treatments again included ^{15}N enriched urea and ammonium nitrate applied by the three methods at a rate of 30 lb N/acre. In this case the two individual nitrogen species of ammonium nitrate were each individually labelled in separate treatments. The degree of labelling of the carriers in this experiment was approximately 5% excess ^{15}N, which would allow not only for a measure of the uptake by the barley of each of the nitrogen species, but also for a measure of the amount of each nitrogen specie remaining in the soil following crop production.

The nitrogen utilization subplots were both seeded and fertilized with the plot seeder, however, difficulties were encountered in the use of the powdered fertilizer and as a result the nitrogen balance subplot was seeded and fertilized by hand. Both plots were treated similarly to the larger yield plots throughout the growing season. At maturity, two rows ten feet long were harvested from each of the nitrogen utilization plots. From each of the nitrogen balance plots three rows of four feet long samples were removed. All samples were individually dried, weighed, threshed and subsamples of the threshed material were retained, ground and analyzed for nitrogen and ^{15}N content.

Following crop removal from the nitrogen balance plots, soil samples were taken from each of the treatments in six inch increments to a depth of four feet. Five samples were taken from each treatment with corresponding depths being bulked. Samples were air dried, ground and analyzed for total nitrogen and ^{15}N content.

Nitrogen was determined by Kjeldahl techniques and ^{15}N was measured on the mass spectrometer (for detailed methods see "Isotope Methodology and Techniques in Soil-Plant Nutrition and Plant Physiology").

Calculations:

Yield N = Mg of nitrogen in the above ground plant parts

= [Kjeldahl N content (mg/gm) x dry wt of straw] + [Kjeldahl N content (mg/gm) x dry wt of grain]

= mg N/8" cylinder

% NDFF = percent of the nitrogen in the plant part which was derived from the fertilizer.

$$= \frac{\text{atom \% } {}^{15}\text{N excess in plant part}}{\text{atom \% } {}^{15}\text{N excess in fertilizer}} \times 100$$

$$\text{\% utilization of fertilizer N} = \frac{\text{mg } {}^{15}\text{N in plant part}}{\text{mg } {}^{15}\text{N applied}}$$

$$= \frac{\text{atom \% } {}^{15}\text{N excess in plant part}}{\text{atom \% } {}^{15}\text{N excess in applied fertilizer}} \times \frac{\text{wt of N in plant part (mg N/cyl.)}}{\text{wt of N applied (mg N/cyl.)}}$$

$$\text{\% fertilizer N in the soil} = \frac{\text{mg } {}^{15}\text{N in the soil}}{\text{mg } {}^{15}\text{N applied}}$$

$$= \frac{\text{atom \% } {}^{15}\text{N excess of total soil N} \times \text{wt of soil N (mg/cyl.)}}{\text{atom \% } {}^{15}\text{N excess of the fert. N} \times \text{wt of fert. N appl. (mg/cyl.)}}$$

% of the fertilizer nitrogen accounted for:

$$= \frac{\text{fert. N in above ground plant parts (mg/cyl.)} + \text{fert. N in soil (mg/cyl.)}}{\text{fertilizer N applied (mg/cyl.)}}$$

RESULTS

In both the nitrogen utilization and nitrogen balance studies none of the treatments were replicated. The data presented are based on results obtained from a single treatment, and as such, no statistical analyses were performed.

Nitrogen Utilization Studies

Results pertaining to crop yield and fertilizer nitrogen usage for the barley and wheat grown in the nitrogen utilization plots are presented in Table 2.2.1. Overall yield values

Table 2.2.1 Crop yield and fertilizer nitrogen uptake parameters for barley and wheat grown in nitrogen utilization plots.

Crop	Treatment	Grain Yield (bu/acre)	Fertilizer Nitrogen Uptake (lb/acre)		% Ndff[1] Grain	% Utilization of Applied Nitrogen	
			Grain	Total Plant		Grain	Total Plant
Barley	NH_4NO_3-B[2]	59.3	6.2	7.2	14.2	20.5	24.0
	NH_4NO_3-SB[3]	62.9	9.9	11.4	21.8	33.0	38.0
	NH_4NO_3-SP[4]	49.8	4.1	4.7	11.6	13.6	15.8
	Urea - B	59.6	8.7	10.3	19.4	29.1	34.2
	Urea - SB	60.9	8.8	10.4	19.8	29.3	34.6
	Urea - SP	64.5	5.1	5.9	11.0	17.1	19.6
Wheat	NH_4NO_3-B	38.9	6.4	7.7	15.3	21.2	25.8
	NH_4NO_3-SB	32.4	6.8	8.3	20.4	22.7	27.7
	NH_4NO_3-SP	40.0	9.5	11.3	22.5	31.6	37.6
	Urea - B	36.9	5.8	7.5	14.0	19.2	24.9
	Urea - SB	32.9	5.5	6.6	15.5	18.3	21.9
	Urea - SP	39.8	5.6	7.0	13.8	18.8	23.4

[1] % plant nitrogen derived from fertilizer

[2] B - Broadcast

[3] SB - Sideband

[4] SP - Seed Placed

obtained for both the barley and wheat in these plots were quite similar to those obtained in the larger yield plots and showed little difference as a result of carrier or placement. Fertilizer nitrogen uptake values were quite low for both crops ranging from (in terms of % total plant uptake) approximately 16 to 38% in barley and from 22 to 38% in wheat. For both crops the majority of fertilizer nitrogen assimilated by the plant was located in the grain; this observation was independent of fertilizer source or placement method.

For barley, the data indicate that the crop was least able to utilize seed placed fertilizer. For both carriers, the amount of nitrogen in the plants derived from fertilizer was least from the seed placement (approximately 11%) and the overall uptake of fertilizer nitrogen was also least from this placement (16 to 20%). There appeared to be little difference between side band and broadcast urea in terms of the amount of nitrogen contributed to the crop and also in terms of percent utilization. The side band ammonium nitrate treatment showed similar values in % NDFF and % recovery to those of broadcast and side band urea, but utilization of broadcast ammonium nitrate by barley was slightly lower.

Data from the wheat plot show few differences in nitrogen utilization by the crop between the different sources and methods of placement. There were essentially no differences in percent utilization of nitrogen from the three placements of urea and little difference between broadcast and side band ammonium nitrate, however, plant utilization of seed placed ammonium nitrate was somewhat higher which is contradictory to the barley results. Since there was no replication it is uncertain as to whether this is a real difference.

Nitrogen Balance Studies

Table 2.2.2 presents results obtained from the nitrogen balance plots relating to utilization by barley and recovery within the soil of the applied fertilizer nitrogen sources. It must be remembered that in this study the two ions of ammonium nitrate were separately labelled in different treatments and utilization and recovery values are based on separate determinations for each ion specie. These plots suffered from a serious weed infestation in combination with poor germination, probably in part due to the amount of movement over these plots during hand seeding and fertilizing. This caused yields to be relatively low. When samples were taken at harvest, the entire sampling area, including both crop and weeds were removed, and after the grain was threshed all of the remaining straw and chaff was saved for analysis.

Yield results from this plot, aside from being low, show marked differences between the urea and ammonium nitrate treatments and between the seed placement as opposed to the broadcast and side band treatments of the carriers (Table 2.2.2). This was not encountered in either the nitrogen utilization or yield plots and the exact cause of this is unknown.

Total nitrogen uptake values for the barley are relatively low. Due to the inclusion of weeds in the straw portion of the plant material analyzed, a relatively small portion of the total nitrogen uptake is accounted for in the grain. However, total recovery of applied nitrogen within the plants in this plot shows

Table 2.2.2 Recovery of applied fertilizer nitrogen sources in crop and soil from barley nitrogen balance plots.

Treatment	Yield bu/ac	Fertilizer Nitrogen Uptake (lb/acre)		% Ndff[1]	% Plant Utilization of Applied Source		% Fertilizer Nitrogen Remaining in Soil			% Total Recovery of Applied Nitrogen Source
		Grain	Total Plant	Grain	Grain	Total Plant	0-6"	6-12"	Total	
$^{*}NH_4NO_3$-B	24.7	1.8	5.3	5.1	6.2	17.9	62.7	3.2	65.9	83.8
$^{*}NH_4NO_3$-SB	37.0	4.2	7.5	8.0	13.9	25.2	43.6	4.3	47.9	73.1
$^{*}NH_4NO_3$-SP	14.8	2.2	5.4	9.1	7.3	18.2	30.4	4.9	35.3	53.5
$NH_4^{*}NO_3$-B	22.0	2.7	6.9	8.0	9.5	24.2	42.6	3.5	46.1	70.3
$NH_4^{*}NO_3$-SB	23.6	2.4	4.7	6.7	8.5	16.5	48.7	3.0	51.7	68.2
$NH_4^{*}NO_3$-SP	11.6	1.6	4.9	8.7	5.5	17.0	33.7	2.7	36.4	53.4
Urea - B	52.7	5.8	10.6	15.9	19.4	35.5	53.2	4.0	57.2	92.7
Urea - SB	49.5	5.9	8.6	15.9	19.5	28.8	45.5	3.7	49.2	78.0
Urea - SP	26.0	3.7	6.8	19.2	12.4	22.8	40.2	1.5	41.7	64.5

[1]% Plant nitrogen derived from specific fertilizer specie labelled (i.e. NH_4, urea, or nitrate).

consistently slightly higher recovery for the urea over either of the ammonium nitrate sources. This is probably directly related to the higher yields obtained from urea since total plant uptake is closely related to yield. Within the urea treatments recovery fell in the order broadcast > side band > seed placed. Recovery of nitrogen from the nitrate tagged ammonium nitrate was greatest from the broadcast treatment with similar lower recoveries being obtained from the side band and seed placed treatments. This would indicate that crop was more able to assimilate nitrate from the broadcast application than from either of the other two applications. On the other hand, total plant utilization of ammonium tagged ammonium nitrate was greatest from the side banding while recovery from broadcast and seed placement were similar and slightly lower. In this case, the indication is that the plant is more able to utilize side band ammonium over the broadcast or seed placement of this source. An overall view of ammonium nitrate would then suggest that when broadcast the crop utilizes more nitrate than ammonia, but when side banded the reverse is true. However, when seed placed the crop recovers ammonium and nitrate in approximately equal proportions. This observation is verified in the % NDFF values which show that when broadcast approximately 8% of the plant nitrogen is derived from nitrate and only 5% from ammonium (thereby an overall % N derived from ammonium nitrate is 13%), however, when side banded 8% of the plant nitrogen is derived from ammonium and 6.7% is from nitrate. In the case of seed placed ammonium nitrate, although the amount of nitrogen in the plant derived from either ammonium or nitrate is greatest from this placement, yields were lowest and therefore total recovery was least.

Data presented in Table 2.2.2 and shown diagramatically in Figure 2.2.1 indicate a large residue of applied nitrogen remaining in the soil after crop removal (varying from 35 to 65% of the applied nitrogen). In all cases, most of this remained in the top 6 inches of soil. The majority of this residual nitrogen would be found bound up in plant roots since the soil contained very little mineral nitrogen at harvest. For both urea and the ammonium labelled ammonium nitrate residual fertilizer nitrogen in the soil from the different placements fell in the order broadcast > side band > seed placed. For the nitrate labelled ammonium nitrate recovery within the soil fell in the order side band > broadcast > seed placed.

Total recovery of applied nitrogen at the end of the growing season both within the crop and in the soil varied between 53 and 93% of the applied nitrogen. Overall recoveries of nitrogen were greatest from urea and therefore the least loss from the system was encountered from this nitrogen source. A greater amount of ammonium labelled ammonium nitrate was recovered than nitrate labelled ammonium nitrate, which would indicate greater losses from the system of nitrate than of ammonia. This may have been due either to leaching or denitrification. The latter mechanism is quite possibly a cause since this year large amounts of rainfall were encountered early in the season and the soil may have been anaerobic for varying amounts of time.

Total recovery of nitrogen from all sources for the different placements was greatest from broadcasting and least from seed

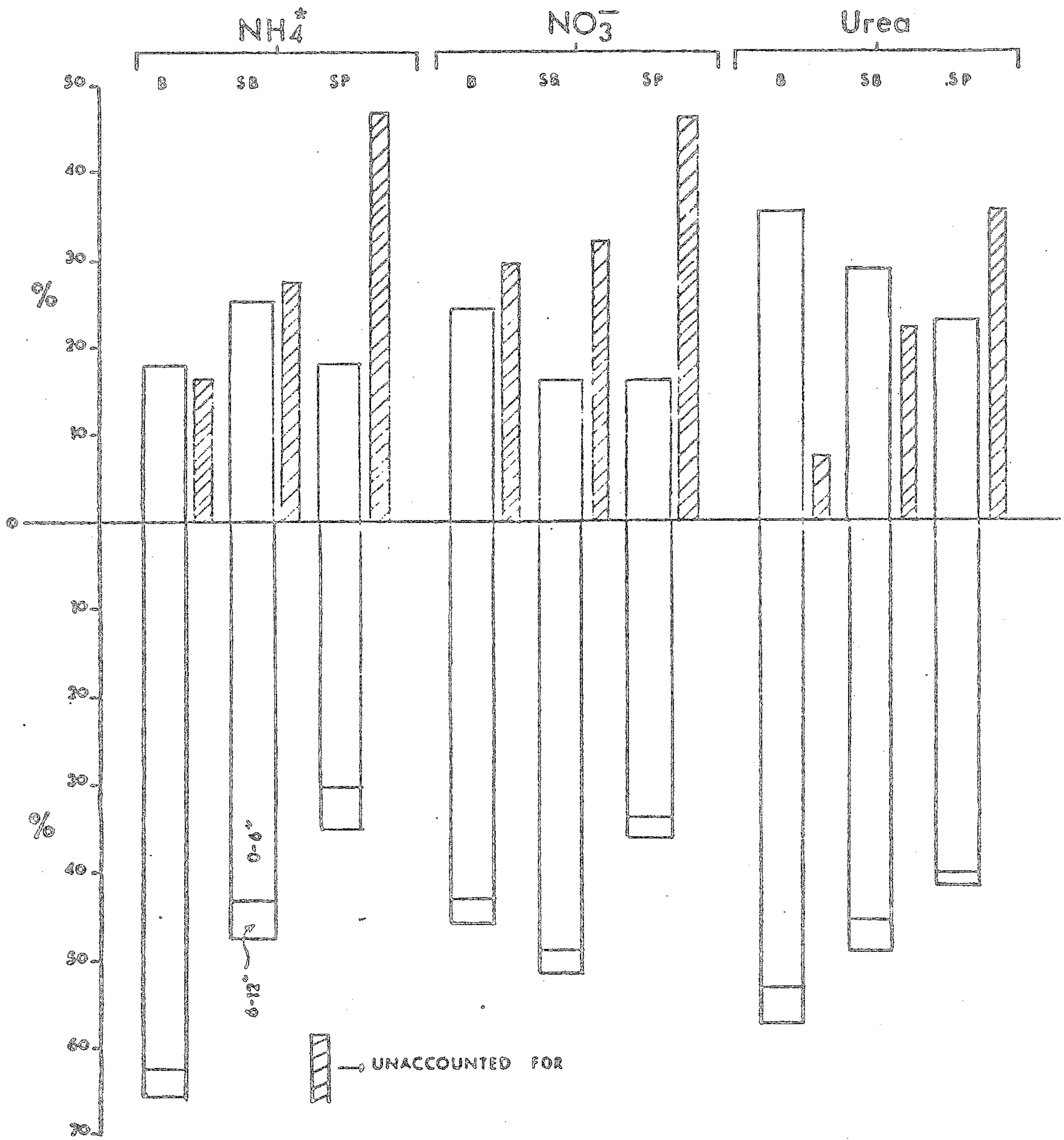


Fig. 2.2.1 Disposition of fertilizer N in barley in above ground plant parts -0, beneath ground plant parts -0, and N unaccounted for: Blaine Lake soil site 1973, broadcast, side-band, and seed-placed application.

placement with side banding being intermediate.

Nitrogen Utilization by Crop and Weeds

As was explained in an earlier section, the plots suffered from a weed infestation and as a result samples were taken from selected treatments to decide whether any relationships could be drawn between nitrogen utilization and crop and weed growth.

Results of this sampling from the nitrogen utilization and nitrogen balance plots are presented in Table 2.2.3. Yield data indicate as was previously mentioned that weeds were more serious in the wheat than in the barley nitrogen utilization plots and weeds were extremely serious in the nitrogen balance plot. On the nitrogen utilization plot fertilizer nitrogen uptake data generally indicates that crops are more able to compete for fertilizer nitrogen when seed placed than when broadcast since fertilizer nitrogen uptake by weeds is considerably lower on seed placed treatments than on broadcast treatments. Data on the percent plant nitrogen derived from fertilizer substantiates this observation.

Results from the nitrogen balance plots do not show these trends. The major point of interest here lies in the relatively better performance of the urea treatment over the ammonium nitrate treatments with the crop utilizing similar amounts of nitrogen as the weed in the urea treatments but the weeds recover considerably more nitrogen than the crop in the ammonium nitrate treatments.

CONCLUSIONS

Since results presented in this report are based on data

Table 2.2.3 Relative uptake of fertilizer nitrogen by crop and weeds from nitrogen utilization and nitrogen balance plots.

Crop	Treatment	Crop Weight lb/ac	Weed Weight lb/ac	Fertilizer Nitrogen Uptake (lb/acre) Crop	Fertilizer Nitrogen Uptake (lb/acre) Weeds	% Ndff Crop	% Ndff Weeds	% Uptake of Applied Fertilizer Source Crop	% Uptake of Applied Fertilizer Source Weeds
A) <u>Nitrogen Utilization Plots</u>									
Barley	NH_4NO_3-B	5412	848	10.1	2.9	22.4	25.1	33.5	9.6
	NH_4NO_3-SP	1681	2288	3.1	2.2	16.6	8.2	10.3	7.5
	Urea - B	4321	633	8.5	1.9	17.1	19.5	28.3	6.1
	Urea - SP	3956	381	3.7	0.4	7.5	8.8	12.3	1.6
Wheat	NH_4NO_3-B	2350	1536	7.7	7.5	25.7	34.3	25.6	25.1
	NH_4NO_3-SP	3818	983	7.9	2.1	18.1	16.8	26.3	6.8
	Urea - B	3108	1236	7.2	6.0	17.1	30.0	24.0	20.0
	Urea - SP	3322	1092	5.4	2.2	13.8	16.6	17.9	8.4
B) <u>Nitrogen Balance Plots</u>									
Barley	$^*NH_4NO_3$-B	1213	3556	1.2	7.3	11.1	19.7	4.0	24.3
	$^*NH_4NO_3$-SP	996	3608	2.2	7.2	21.9	17.6	7.3	24.1
	$NH_4{}^*NO_3$-B	1207	3444	2.0	7.7	15.5	20.0	6.7	25.5
	$NH_4{}^*NO_3$-SP	742	4689	1.6	10.3	18.9	18.7	5.4	34.2
	Urea - B	3098	1728	5.8	5.6	18.8	29.0	19.2	18.9
	Urea - SP	2052	2961	4.2	6.9	19.2	19.6	13.9	22.8

from a single trial conducted on one soil type in one year it is difficult to make any general conclusion regarding the relative efficiency of urea and ammonium nitrate and different placement methods. However, it is generally agreed that the approach taken in this study, having large yield plots representing farm conditions adjacent to small plots in which tracer nitrogen is utilized, make possible detailed determination on the relative usefulness of different sources and placement of nitrogen. It is also agreed that treatment replication facilitates data interpretation.

The data obtained this year indicate that on the Blaine Lake soil there are no great differences between the overall utilization by wheat and barley of urea and ammonium nitrate. Recovery of nitrogen with the crop from both carriers, particularly in barley, was least from the seed placement, with overall recoveries from broadcasting and side banding being essentially equal. Considerable quantities, amounting to 35 to 65% of the applied nitrogen, remain in the soil in organic bound forms following crop growth. These results are in close agreement to results obtained in a similar trial on Blaine Lake soil conducted in 1972. Thus, this soil does not show differences when the two carriers, urea and NH_4NO_3, are utilized. The large uptake of broadcast ^{15}N by the weeds, and the general poor plant utilization of fertilizer N in a year, with generally good growing conditions, re-emphasizes the fact that nitrogen fertilization must be combined with other good cropping practices for adequate results to be obtained.

The amount of N lost from the system was inversely correlated with plant uptake indicating the need for adequate placement for good fertilizer efficiency.

3. STUDIES ON THE PHOSPHORUS AND NITROGEN NUTRITION OF FABABEANS

INTRODUCTION

As attempts are made to diversify Western Canadian agriculture, attention is focussed on alternative protein sources that could replace expensive imported sources used in livestock and poultry feeding rations. Shortages of high protein feed sources have forced current prices to high levels placing legume crops in an extremely competitive position with traditional prairie crops such as wheat and barley.

The fababean or horse bean (*Vicia faba* L.) was one of the obvious alternative crops, as it is a good protein source and appears to have the ability to withstand some of the extremes of the Western Canadian environment. Little, however, is known about the fertilizer requirements of this bean, or about the extent of its rooting system and its ability to take up nutrients from different soil depths under the semiarid conditions prevailing in Saskatchewan.

In 1973, this project was started with the objectives of assessing the efficiency of phosphate use by fababeans from different placements of phosphorus fertilizer and evaluating the contributions of soil, fertilizer and symbiotically fixed nitrogen to the plant.

EXPERIMENTAL METHODS

Two sites were selected for the establishment of field trials on adjacent fields of Blaine Lake silty clay loam soil. One site was on a summerfallow field high in nitrate nitrogen, while the second site was on a wheat stubble field low in nitrate nitrogen.

Results of analyses of soil samples taken from each location prior to seeding are presented in Table 3.1.

Table 3.1 Results of analyses of soils from sites selected for fababean trials.

Cooperator/ Location Crop	Soil Type/ Texture	Depth in.	NO_3-N	$NaHCO_3$ ext. P	$NaHCO_3$ ext. K	pH	Cond. mmho/cm
			lb/acre				
Peters	B:sicl	0-6	42	12	620	6.7	0.4
SW13-45-5-W3		6-12	22	4	290	6.9	0.4
		12-24	14	3	535	7.8	0.6
Summerfallow		24-36	7	4	575	8.2	0.7
		36-48	17	2	655	8.2	1.1
Peters	B:sicl	0-6	5	9	345	7.3	0.3
NW13-45-5-W3		6-12	3	3	235	7.4	0.3
		12-24	2	3	475	7.9	0.5
Stubble		24-36	2	2	540	8.2	1.0
		36-48	8	2	505	8.2	1.2

Small plots of the randomized complete block design were established at both sites. Each plot contained fifteen treatments replicated four times. Fertility treatments included in these plots (Table 3.2) consisted of the application of phosphorus at rates of 15, 30, 60 and 90 lb P_2O_5/acre in both sideband and with the seed placements and at a rate of 60 lb P_2O_5/acre in a deep placement (12 inches below the soil surface). Additional treatments included the sideband application of nitrogen at a rate of 75 lb N/acre in separate treatments where phosphorus was applied at rates of 30 and 60 lb P_2O_5/acre sidebanded and seed placed and at 60 lb P_2O_5/acre deep placed. In certain treatments, as indicated in Table 3.2, ^{15}N enriched NH_4NO_3 and ^{32}P enriched $NH_4H_2PO_4$ were applied to allow for detailed nitrogen and phosphorus uptake measurements to be made. In the remaining treatments regular pelleted fertilizers were applied.

Table 3.2 Fertility treatments used in fababean experiments.

Treatment Number	Nutrients Applied (lb/acre)		Nutrient Placement	
	N[1]	P_2O_5[2]	N	P_2O_5
1	0	0		
2	0	15		Sideband
3	0	30*		Sideband
4	75*	30	Sideband	Sideband
5	0	60*		Sideband
6	75*	60*	Sideband	Sideband
7	0	90		Sideband
8	0	15		Seed placed
9	0	30*		Seed placed
10	75	30	Sideband	Seed placed
11	0	60*		Seed placed
12	75	60*	Sideband	Seed placed
13	0	90		Seed placed
14	0	60*		Deep placed
15	75	60*	Sideband	Deep placed

[1] All nitrogen applied as ammonium nitrate (34-0-0)

[2] All phosphorus applied as mono-ammonium phosphate (11-55-0)

* Isotope enriched fertilizer applied

Prior to seeding, Treflan was applied for weed control at recommended rates (1 lb active/acre) and incorporated with a discer and harrows. Diana fababean seeds were innoculated with a commercial inoculum. Seeding of the beans as well as all sideband and seed placed fertilizer placements was accomplished by a custom built cone-type plot seeder. Difficulty was encountered in obtaining uniform dispensing of seed and fertilizer. In the treatments containing deep placed phosphorus, application of the fertilizer was accomplished by dissolving the carrier in water and injecting the solution at depth (12 inches) through a syringe at 6 inch intervals over the length of the seed row. The plots were each hand weeded twice through the growing season since adequate control was not obtained from the herbicide application. An infestation of blister beetles at flowering time was easily controlled with malathione.

Plant material samples were taken from all treatments on a regular basis commencing 35 days after seeding and continuing on a bi-weekly basis until harvest. Two plants were removed from each treatment at each sampling date for nitrogen and phosphorus uptake evaluation. Further foliage and root core samples were taken from specific treatments for symbiotic nitrogen fixation assessment. All samples were air dried, weighed, ground and analyzed for total nitrogen, ^{15}N, total phosphorus, and ^{32}P content.

Twice during the summer, and again at harvest, root core samples were taken from various treatments on both plots. These were washed and mounted, and measurements taken to evaluate the extent of root growth.

At final harvest (115 days after seeding) samples were taken over a ten foot length of the two central rows of all treatments. These were air dried, weighed, threshed and subsampled for final nitrogen and phosphorus uptake evaluation.

RESULTS

Response of Fababeans to Applied Phosphorus and Nitrogen

A summary of the yield data is presented in Table 3.3 and Figure 3.1. The yield of the beans on the fallowed plot in most instances was more than twice that of the stubble plot. The absence of any response to phosphate on the stubble plot, together with the very strong response to N fertilization suggests that the major factor restricting yields on the stubble plot was a deficiency of nitrogen. This conclusion is supported by the very low levels of available soil nitrogen measured at time of seeding on the stubble plot and the visual symptoms of acute nitrogen deficiency exhibited by the crop during the growing season. Such observations would suggest that there was little symbiotic nitrogen fixation, and this was confirmed by examining a number of plant roots selected at random. The lack of active nodules was confirmed both visually and through acetylene reduction analyses.

Phosphate fertilization on the fallow plot increased yields from twenty-five to approximately forty-five percent (sidebanded), as the rate was increased from 15 to 60 lb of P_2O_5/acre. Response to P fertilization was similar with seed placement. The deep placement of phosphate fertilizer was less effective in increasing yields. Yield response to side banding and seed placement seemed to be a function of the available phosphorus level of the soil,

Table 3.3 The effect of phosphorus and nitrogen fertilization on the yield of fababeans.

Treatment: N applied (lb/acre)	Treatment: P applied (lb/acre)	P placement	Yield (cwt./acre): Bean	Yield (cwt./acre): Straw	Bean/Straw Ratio
		SUMMERFALLOW PLOT			
0	0		20.2	31.3	0.65
0	15	Sideband	25.0	39.1	0.64
0	30	Sideband	26.2	38.3	0.70
75	30	Sideband	23.7	35.4	0.69
0	60	Sideband	29.2	42.9	0.70
75	60	Sideband	32.3	44.1	0.74
0	90	Sideband	28.4	36.2	0.79
0	15	Seed placed	20.2	31.8	0.64
0	30	Seed placed	26.4	35.0	0.76
75	30	Seed placed	19.6	24.5	0.83
0	60	Seed placed	28.8	40.9	0.71
75	60	Seed placed	24.7	37.5	0.67
0	90	Seed placed	31.8	39.1	0.82
0	60	Deep placed	25.9	40.5	0.64
75	60	Deep placed	25.4	37.5	0.68
		STUBBLE PLOT			
0	0		7.3	16.6	0.47
0	15	Sideband	6.8	14.9	0.44
0	30	Sideband	7.1	14.0	0.49
75	30	Sideband	16.1	21.4	0.75
0	60	Sideband	9.6	16.4	0.58
75	60	Sideband	12.9	18.4	0.72
0	90	Sideband	9.2	14.9	0.61
0	15	Seed placed	9.3	15.5	0.59
0	30	Seed placed	8.9	15.2	0.56
75	30	Seed placed	13.8	21.8	0.61
0	60	Seed placed	6.7	13.0	0.52
75	60	Seed placed	11.4	15.9	0.88
0	90	Seed placed	8.9	15.9	0.56
0	60	Deep placed	12.1	16.6	0.71
75	60	Deep placed	14.0	17.9	0.78

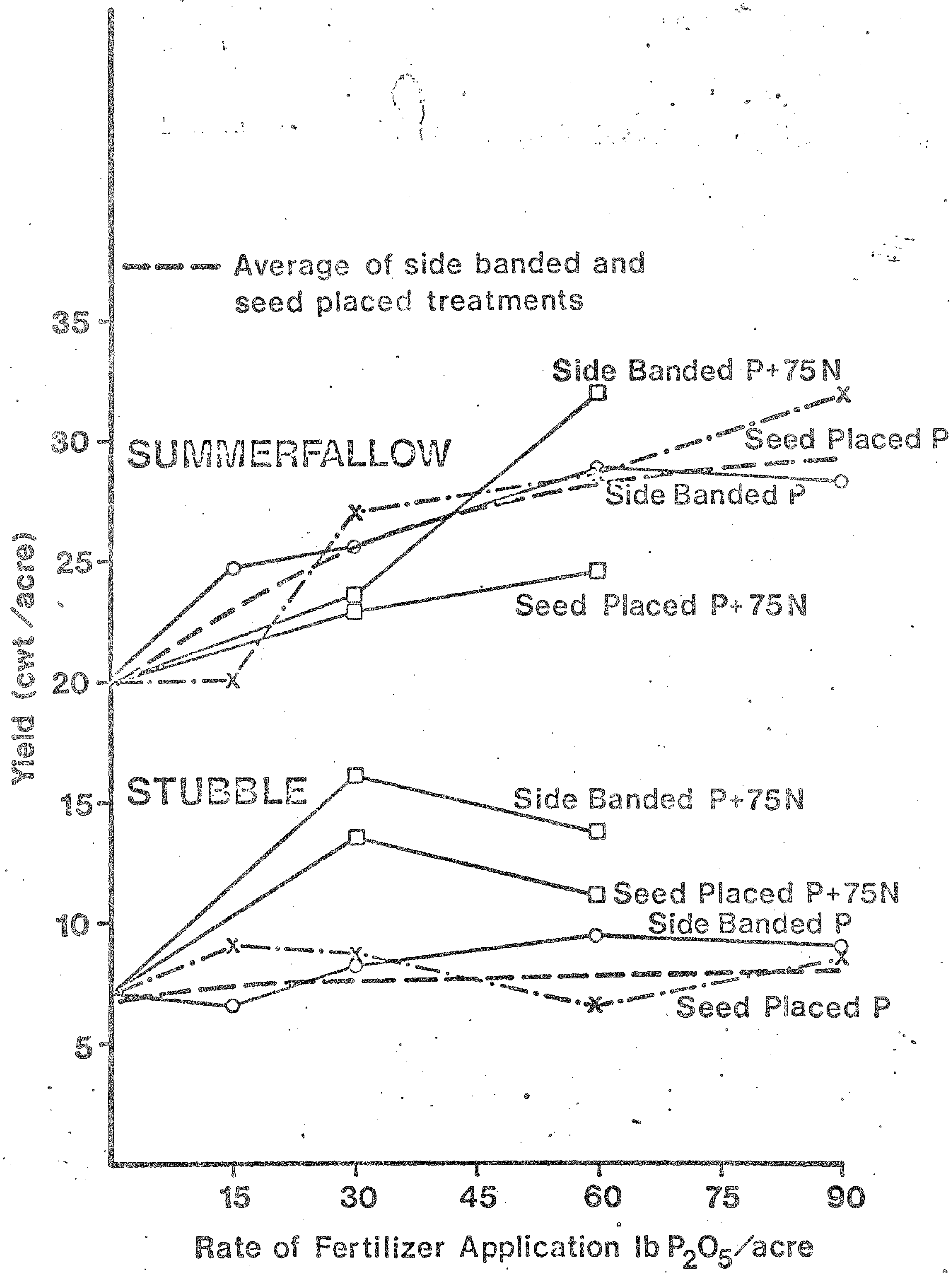


Figure 3.1 Response of fababeans to applied fertilizer.

and would only become apparent when there was adequate supply of NO_3-N in the soil, as was the case on the summerfallow site. Here, no response to applied nitrogen was obtained even though it was determined through acetylene reduction techniques that the plants were not fixing nitrogen. If the fababeans had been inoculated with the correct rhizobia, or if the inoculation techniques had been adequate, it is possible that phosphate response would have been obtained on the stubble plot.

Bean/straw ratio values given in Table 3.3 tend to indicate that the fababean seed production becomes more efficient as amount of available phosphate is increased, given adequate nitrogen, since on the summerfallow plot bean/straw ratios increase with increased rates of phosphorus applied. On the stubble plot there was a marked increase in the ratio of grain to straw production in the treatments where nitrogen was supplied. These data would indicate that seed production in fababeans becomes more efficient when adequate amounts of both phosphorus and nitrogen are supplied either as fertilizer and/or by natural means.

Phosphorus Utilization

The relationship between percentage of phosphorus in the plant tissue and time is depicted in Figure 3.2 and Table 3.4. These data show a progressive decrease in % P with time. The stubble plot values were higher than the summerfallow plot throughout the growing season, thereby giving additional evidence of the nitrogen deficiency which severely restricted stubble yields. The very low P content of the control samples at the initial sampling date suggests that the seedling plant has difficulty feeding on soil-P. In contrast, the bean was able to take up phosphorus much more

Table 3.4 Phosphorus content of fababean plant material at various growth stages.

Treatment lb/acre N	P_2O_5	#	Method of Placement	35	48	61	75	88
			SUMMERFALLOW PLOT					
0	0	1		.19±.02	.33±.01	.29±.01	.32±.09	.19±.02
0	15	2	Side Band 5 cm	.23±.04	.24±.01	.26±.02	.21±.03	.17±.01
75	30	4		.25±.02	.26±.03	.25±.02	.25±.01	.19±.04
0	90	7		.35±.05	.27±.02	.26±.02	.26±.03	.18±.01
0	15	8	Seed Placement	.29±.10	.32±.01	.27±.03	.25±.09	.18±.08
75	30	10		.23±.04	.24±.01	.24±.02	.21±.05	.16±.03
0	90	13		.35±.04	.28±.02	.23±.01	.21±.03	.18±.01
			STUBBLE PLOT					
0	0	1		.34±.05	.39±.02	.28±.04	.28±.07	.32±.07
0	15	2	Side Band 5 cm	.38±.05	.36±.03	.36±.04	.38±.09	.31±.05
75	30	4		.38±.06	.37±.03	.35±.06	.31±.02	.25±.02
0	90	7		.42±.03	.41±.04	.38±.02	.43±.03	.33±.04
0	15	8	Seed Placement	.41±.03	.42±.04	.40±.03	.38±.05	.31±.02
75	30	10		.37±.01	.39±.04	.33±.07	.27±.02	.26±.10
0	90	13		.44±.06	.35±.02	.40±.04	.36±.04	.30±.01

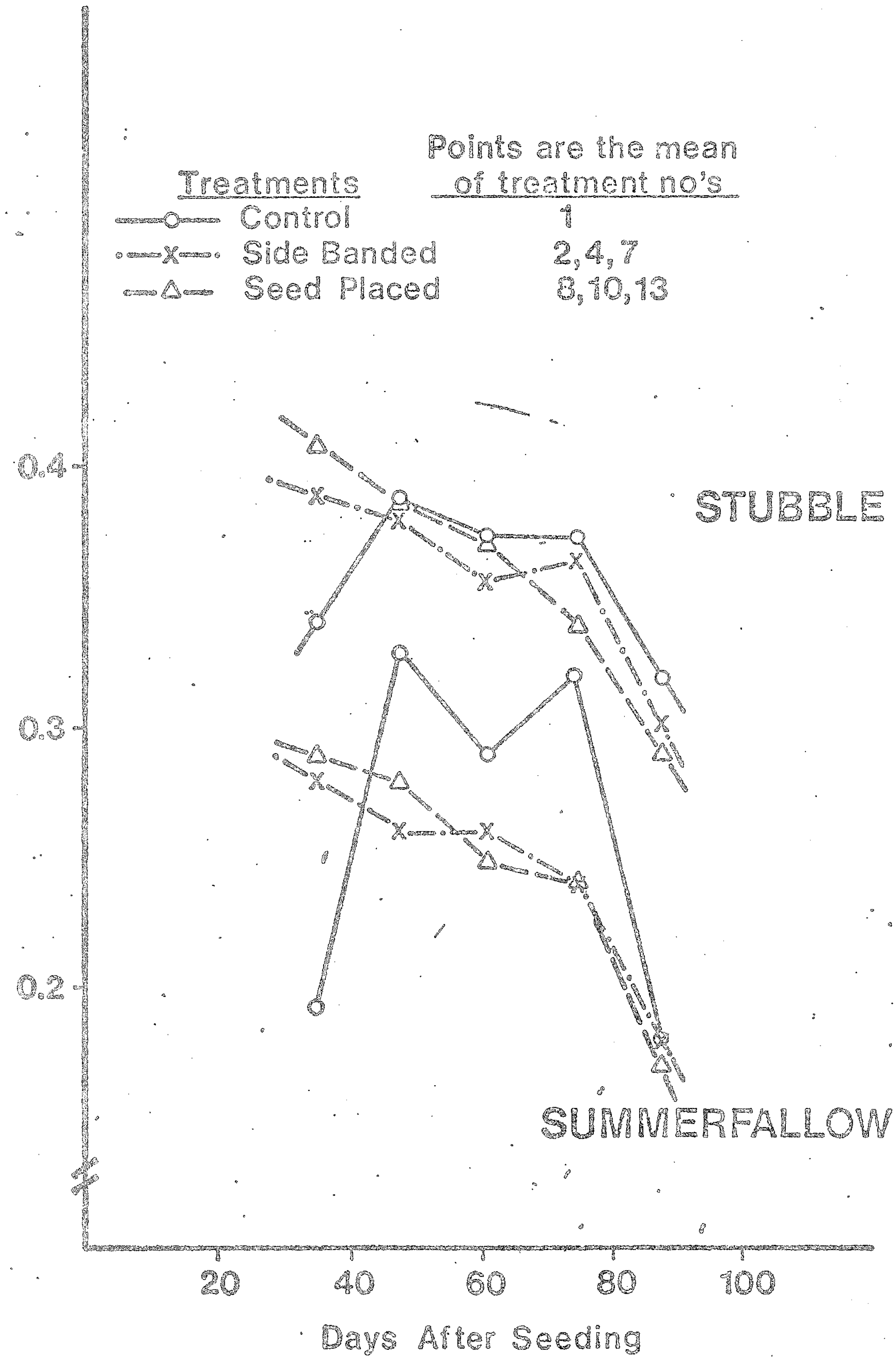


Figure 3.2 The effect of P fertilizer placement and time on the % P in the plant.

readily from the fertilized treatments. In general, the P content of the tissue at later sampling dates was identical on the stubble plot. The control treatment on the fallow plot contained more P than either of the P fertilizer placements; this probably reflects a dilution in P content due to the large yield response.

As would be expected, similar observations can be drawn from the data for the ^{32}P-labelled treatments given in Fig. 3.3. In the early stages of growth, the deep placement of P fertilizer results in the fertilizer being positionally unavailable, and consequently, the P content was lower than either the seed placed or sidebanded treatment.

The different "A" values obtained with time of sampling from sidebanded, seed placed and deep placed phosphate treatments are presented in Figure 3.4.

Sidebanding and seed placements, judging from the yield data results, were not significantly different on both plots, but comparable "A" values were larger with sidebanded fertilizers than seed placements. The "A" values indicated that the seed placed fertilizer was more efficiently used. Figure 3.4 shows that, with higher "A" values in this order: deep placed > side-banded > seed placed, fertilizer phosphate availability decreased with increase in "A" values.

The "A" values changed with time and with placement. Values obtained for deep placed phosphate treatments were very high at the first sampling date (35 days after seeding). This indicated low utilization of applied phosphate presumably due to the fact that roots have not fully explored this soil depth. With increasing growth, the "A" values decreased until at 48 days in

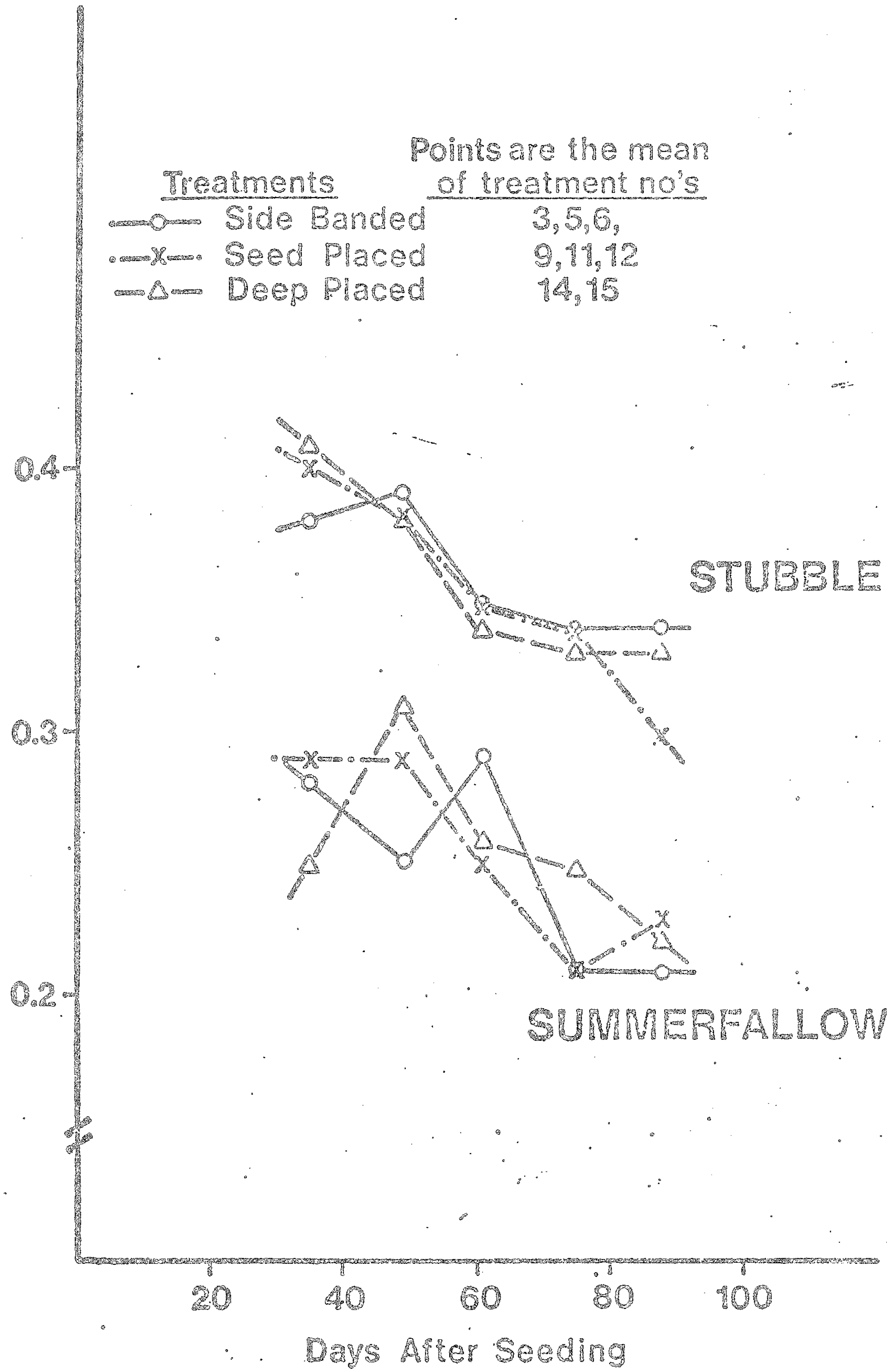


Figure 3.3 The effect of ^{32}P fertilizer placement and time in the % P in the plant.

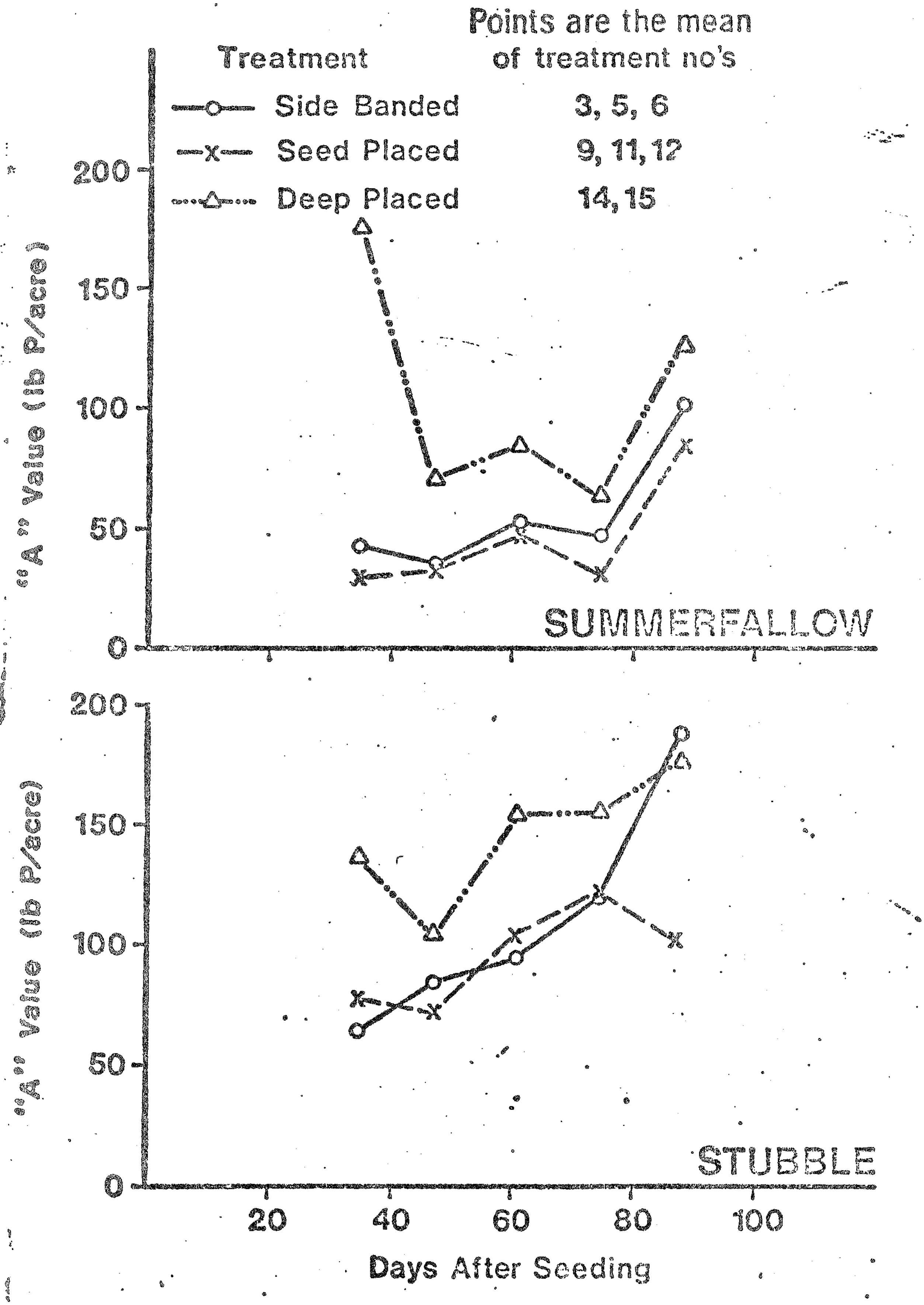


Figure 3.4 The effect of fertilizer placement and time on "A" values.

the stubble plot, and at 75 days on the summerfallow plot, "A" values obtained from deep placed phosphate treatment were comparable (if slightly higher) than those obtained from seed placed and side-banded P treatments. All "A" values increased from day 75 to the penultimate harvesting at 87 days, indicating greater utilization of soil phosphate, presumably due to greater exploration of the lower soil depth as the profile dried out and moisture became limiting.

Owing to a technical fault in the counting equipment, samples collected at the final harvest (115 days from seeding) were not used as the counts were close to background when analyzed and statistical accuracy could not be attained. The final harvest was used for yield data and for ^{31}P data.

The effect of P placement can be assessed from the summary isotopic data shown in Table 3.5. This data is based on yield of the fababean grain at harvest and does not include phosphate held in the straw or roots. Hence the percentage utilization of fertilizer P refers to the utilization of added P by the fababean seed and the percentage utilization of added P of the whole plant (seed, straw and roots) would be much higher.

Data in Table 3.5 show that the percentage utilization of added fertilizer P on all treatments varied from a low of 1.5% on the 0 N 30 P_2O_5 sideband treatment on the stubble plot to a high of 9.9% on the 0 N 30 P_2O_5 sideband treatment on the summerfallow plot. In general, there was little difference in the uptake of P for seed placed or sidebanded, although seed placed P was more efficiently used in the majority of cases. For instance, comparison of the results of the 0 N 60 P_2O_5 seed placed and side-

Table 3.5 Assessment of the effect of P placement using selected isotope derived data.

Treatment	0 N	30 P_2O_5	0 N	60 P_2O_5	75 N	60 P_2O_5
Measurement	Fallow	Stubble	Fallow	Stubble	Fallow	Stubble
Side Band						
Yield of P (lbs/acre)[1]	7.2	2.8	7.3	4.1	9.4	6.2
% PDFF	18.01	7.05	27.4	13.21	13.47	11.38
Yield of Fert. P (lb/ac)[2]	1.30	0.20	2.00	0.54	1.27	0.71
% utilization of Fert. P[3]	9.92	1.53	7.63	2.06	4.85	2.71
"A" values (lb P/acre)[4]	60(60)	173(173)	69(70)	172(171)	170(168)	204(204)
Seed Placed						
Yield of P (lbs/acre)	7.0	4.1	7.2	2.8	7.2	5.1
% PDFF	12.72	13.91	27.78	16.93	23.39	22.25
Yield of Fert. P (lb/ac)	0.89	0.57	2.00	0.47	1.68	1.13
% utilization of Fert. P	6.79	4.35	7.63	1.79	6.41	4.31
"A" values (lb P/acre)	90(90)	81(81)	68(68)	129(128)	86(86)	92(92)
Deep Placed						
Yield of P (lbs/acre)	-	-	7.5	5.3	8.2	6.3
% PDFF	-	-	19.76	12.59	16.27	12.60
Yield of Fert. P (lb/ac)	-	-	1.48	0.67	1.33	0.79
% utilization of Fert. P	-	-	5.65	2.56	5.08	3.02
"A" values (lb P/acre)	-	-	106(106)	182(182)	135(144)	182(182)

[1] Refers to yield of P in seed--does not include P in straw or roots.

[2] Obtained from harvest 88 days after seeding.

[3] Refers to % utilization of fertilizer P in seed--does not include P in straw or roots.

[4] A values derived from data shown here. A values in parentheses obtained from 88 day harvest.

banded treatments on summerfallow show almost identical results. On stubble where P fertilizer was not limiting growth, the seed placed P was more efficiently used.

The uptake of fertilizer P by plant is a function of the availability of the soil P and the total weight of the plant material produced. Results obtained are in good agreement with the hypothesis that at 25% of plants total dry weight they will have already accumulated as much as 75% of their total phosphorus in demand. Fababean, like other legumes, therefore, need adequate P throughout the growing season.

The experiment also provided an opportunity to examine the uptake of phosphorus from equivalent amounts of both ^{32}P and ^{31}P fertilizer. The radioactive fertilizer treatments were designed to complement the field experiment. The rates and placements of radioactive fertilizer were identical to those used as the normal phosphate fertilizer. It was observed that at any sampling date, the average percentage P of the eight radioactive treatments is equal to the average of percentage P of the other six non-radioactive phosphate fertilizer, the various rates and methods of placements, notwithstanding. A summary of these observations are presented in Table 3.6.

These observations confirm the efficiency of labelled fertilizers in tracer studies, especially in soil-plant nutrition research and further shows that the plant does not discriminate between the two isotopes (^{32}P, ^{31}P) of phosphorus.

Table 3.6 Summary of % ^{32}P and % ^{31}P uptake data.

Tissue samples taken at (days) after seeding	Summerfallow		Stubble	
	^{32}P labelled treatments	Non-labelled P treatments	^{32}P labelled treatments	Non-labelled P treatments
35	.27 ± .03	.28 ± .06	.40 ± .03	.40 ± .03
48	.28 ± .03	.29 ± .04	.38 ± .01	.38 ± .03
61	.27 ± .02	.25 ± .02	.35 ± .06	.37 ± .03
75	.22 ± .03	.23 ± .03	.34 ± .06	.36 ± .06
88	.22 ± .02	.18 ± .01	.34 ± .05	.29 ± .03
115 - Pods	.28 ± .03	.28 ± .02	.44 ± .02	.41 ± .02
- L+S*	.07 ± .01	.07 ± .07	.17 ± .09	.27 ± .01

*L+S = Leaves and stems

Nitrogen Utilization

The nitrogen content of fababean plant material taken from both plots at various growth stages is shown in Table 3.7. These

Table 3.7 Nitrogen content of fababean plant material at various growth stages.

Sampling Time (days after seeding)	Nitrogen Content (%)					
	Summerfallow Plot			Stubble Plot		
	0-0[1]	75-30	75-60	0-0	75-30	75-60
35	4.54	5.04	5.27	4.48	4.25	3.89
48	3.96	4.22	4.10	3.26	2.79	3.05
61	3.47	3.46	3.92	2.60	2.17	2.48
75	3.08	3.45	2.91	1.97	2.03	2.11
88	2.20	2.54	2.75	1.27	2.07	1.97
115 (harvest) pods	3.43	3.38	3.55	2.31	2.43	2.34
leaves and stems	1.33	1.00	1.13	0.73	0.94	0.70

[1]Rate of applied nitrogen and phosphorus respectively.

results are based on samples taken from the check treatments and the treatments on which ^{15}N enriched nitrogen fertilizers were applied. The summerfallow seeded plants had a considerably higher nitrogen content, particularly in the later growth stages than did the stubble seeded plants. In both cases nitrogen content declined with plant age. On the summerfallow site the plants which received both nitrogen and phosphorus consistantly contained greater quantities of nitrogen than did the non-fertilized plant, but there was no apparent difference in the nitrogen content of the plants receiving different levels of applied phosphorus. On the stubble site, the control treatment plants initially had a higher nitrogen content than the fertilized plant, but beyond the 61st day the nitrogen content of the non-fertilized plants fell below that of the fertilized plants. Again there was no difference in plant nitrogen content that could be attributed solely to the different levels of applied phosphorus.

Measurements taken on random plant samples throughout the growing season using acetylene reduction techniques clearly indicated the lack of effective nodulation on the plant roots. As a result, the fababean plants were totally dependent upon soil and any applied fertilizer nitrogen. It was apparent in the yield data that there were sufficient quantities of available soil nitrogen present on the summerfallow site to attain reasonable crop growth. This was not the case on the stubble site where additions of fertilizer nitrogen resulted in fairly large yield increases. However, data obtained through ^{15}N measurement techniques (Table 3.8) indicate that the fababean plants grown on the summerfallow plot as well as those grown on the stubble plot

Table 3.8 Utilization of fertilizer nitrogen by fababeans as measured by ^{15}N techniques.

Sampling Time (days from seeding)	% Ndff[1]		"A" value (lb N/acre)		% utilization	
	75-30[2]	75-60	75-30	75-60	75-30	75-60
	SUMMERFALLOW PLOT					
35	35.4	34.5	159	160	5.5	3.7
48	39.5	38.6	134	138	18.0	19.3
61	34.3	37.2	189	149	34.8	44.0
75	25.8	22.0	292	310	40.8	39.5
88	12.2	11.5	938	1400	34.2	36.5
115 (harvest) pods	14.7	14.4	644	611	24.7	32.5
leaves and stems	18.1	16.5	453	508	6.6	9.7
harvest total					31.3	42.2
	STUBBLE PLOT					
35	54.0	42.8	76	119	11.7	5.1
48	49.3	44.4	89	109	18.2	20.5
61	40.3	43.1	137	114	(X)	38.2
75	42.2	41.5	131	125	30.3	31.7
88	38.2	21.3	377	373	35.0	28.9
115 (harvest) pods	26.7	22.1	425	324	(X)	22.4
leaves and stems	33.2	27.9	232	223	9.7	6.4
harvest total						28.8

[1] Percent plant nitrogen derived from fertilizer

[2] Rate of applied nitrogen and phosphorus respectively

(X) Sample weight missing

readily assimilated applied fertilizer nitrogen. In the early growth stages (up to 48 days) applied fertilizer nitrogen contributed almost 40 and 50% respectively of the nitrogen contained in the summerfallow and stubble seeded plants. On the summerfallow site, this value dropped rather sharply beyond the 61st day of growth, and by harvest time fertilizer nitrogen comprised less than 20% of the total nitrogen assimilated. It is apparent that by that point the plants had utilized essentially all of the available fertilizer nitrogen since total recovery of applied fertilizer did not increase beyond the near 40% value obtained at this time. Soil nitrogen then became the prime contributor of the plant nitrogen. Data indicate that the stubble seeded plants continued to utilize fertilizer nitrogen until the 75th day, at which point total fertilizer recovery tended to reach a minimum of slightly greater than 30% and beyond which "percent plant nitrogen derived from fertilizer" value declined.

Data presented in Table 3.9 gave an indication of the final nitrogen content and total nitrogen uptake at harvest time of the beans in the various treatments in both plots. Overall, the beans from the summerfallow site had a considerably higher protein and nitrogen content than those from the stubble plot; with total nitrogen uptake on the former plot being considerably higher. Only on the stubble plot did any of the fertility treatment result in marked differences in total nitrogen uptake; and this, as expected, was due to applied fertilizer nitrogen resulting in an increased nitrogen uptake. None of the fertility treatments appeared to affect the protein content of the bean.

Table 3.9 The effect of phosphorus and nitrogen fertilization on the nitrogen utilization of fababeans.

Treatment N Applied	P Applied	P Placement	Bean Protein[1] Content (%)	Straw Nitrogen Content (%)	Nitrogen Uptake (lb/acre) Bean	Straw	Total
			SUMMERFALLOW PLOT				
0	0		28.2	0.96	91.3	30.0	121.3
0	15	Sideband	25.2	0.76	100.6	29.7	130.3
0	30		27.8	0.74	116.3	28.3	144.6
75	30		27.9	0.71	105.5	25.1	130.6
0	60		27.4	0.67	127.9	28.7	156.6
75	60		27.1	0.71	139.8	31.3	171.1
0	90		26.6	0.71	121.0	25.7	146.7
0	15	Seed Placed	26.1	0.73	84.3	23.2	107.5
0	30		26.3	0.67	111.0	23.5	134.5
75	30		25.5	0.67	80.1	16.4	96.5
0	60		26.2	0.70	120.9	28.6	149.5
75	60		25.2	0.68	99.4	25.5	124.9
0	90		27.9	0.76	141.2	29.7	170.9
0	60	Deep Placed	26.4	0.65	109.2	26.3	135.5
75	60		26.9	0.64	105.7	24.0	129.7

Table 3.9 (continued)

Treatment N Applied	P Applied	P Placement	Bean Protein Content (%)[1]	Straw Nitrogen Content (%)	Nitrogen Uptake (lb/acre)		
					Bean	Straw	Total
			STUBBLE PLOT				
0	0		20.1	0.73	23.4	12.1	35.8
0	15	Sideband	21.8	0.74	23.7	11.0	34.7
0	30		21.4	0.67	24.3	9.4	33.7
75	30		21.0	0.55	54.1	11.8	65.9
0	60		21.9	0.73	33.7	12.0	45.7
75	60		20.7	0.55	42.8	10.1	52.9
0	90		21.0	0.64	30.9	9.5	40.4
0	15	Seed Placed	22.6	0.77	33.6	11.9	45.5
0	30		22.2	0.74	31.7	11.2	42.9
75	30		18.6	0.59	41.0	12.9	53.9
0	60		19.9	0.73	21.3	21.4	42.7
75	60		18.9	0.48	34.5	7.6	42.1
0	90		21.9	0.67	31.2	10.7	41.9
0	60	Deep Placed	21.5	0.64	41.7	10.6	52.3
75	60		18.7	0.50	41.9	9.0	50.9

[1] Bean protein based on % N at 13.5% moisture x 6.25.

Root Distribution Studies

Examination of the depth and proliferation of the root samples was carried out at various time intervals between seeding and harvest. Root cores were washed free of soil and the root distribution obtained has been depicted in Fig. 3.5. The tap root of the fababean was traced to depths in excess of 120 cm but the main proliferation of fine roots were in the top 15-30 cm depth. The tap root could not be traced to very low depths until the latter part of the growth season. Some indication of the root activity can be seen in the "A" values which increased with deeper profile exploration by the soil roots in the latter part of the season.

SUMMARY AND CONCLUSIONS

Results obtained from two field trials conducted in 1973 can be summarized as follows:

1) Reasonable yields of fababeans were obtained when the crop was provided with adequate levels of nitrogen and phosphorus and effective weed control was maintained.

2) Supplied with adequate nitrogen, the fababeans responded well to applied fertilizer phosphate when the $NaHCO_3$ extractable P level of the soil was less than 12 ppm in the top 6 inches. Similar crop yields were obtained from sidebanded and seed placed phosphate, however, total uptake of applied phosphorus fell in the order: seed placed > sideband > deep placed. The optimum rate of phosphate application was approximately 60 lb P_2O_5/acre.

3) Since the fababean plants did not successfully nodulate, a good response to both soil and fertilizer nitrogen was obtained.

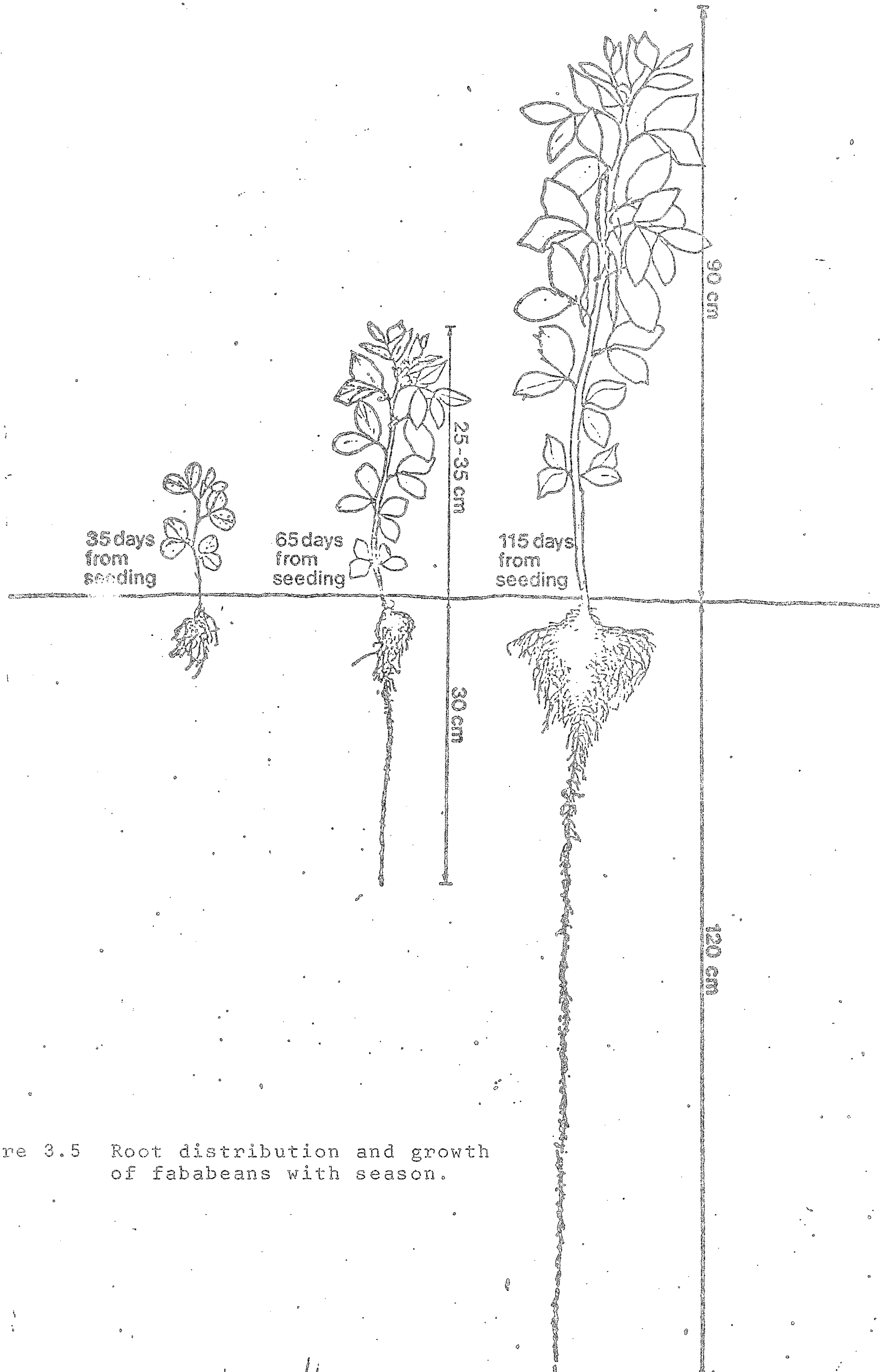


Figure 3.5 Root distribution and growth of fababeans with season.

For successful production, care will have to be taken to ensure adequate plant nodulation through the proper application of the correct inoculum for fababeans.

4) It is apparent that fababeans should be seeded early in the spring since this crop took well over 100 days to reach maturity.

4. SOIL PRODUCTIVITY STUDY IN THE SWIFT CURRENT MAP AREA

INTRODUCTION

This productivity study was initiated in 1971 along with the basic soil survey in the Swift Current (72J) map area. It was continued in 1972 and again in 1973 with the continued co-operation of the Agriculture Canada Research Station, Swift Current. The purpose of the study is to obtain some new productivity data for selected soils within the map area for inclusion in the soils report. While there is considerable yield information which can be used to evaluate the productivity of different soil associations, there is little or no comparative yield information which can be used to evaluate the productivity of map units within an association. Until now, the discussion of the productivity of the various field separations in the soil report has been based mainly on field observations with very little data to reply on. This study is the first attempt to obtain some data to indicate the significance of some of the field separations being made.

METHODS

The study has been restricted to one map unit of the Haverhill Association which occurs on gently and moderately rolling topography and is described as: Dominantly Orthic Brown series with a significant combination of Calcareous Brown and Orthic Regosol series. Minor inclusions of Cumulic Eluviated series have been identified as occurring in lower slope positions. The productivity study for wheat was continued on five summerfallow fields (Appendix D) which were the same fields as used in 1971 and adjacent to those used in 1972. The forage study was continued on the same five fields used in 1972 (Appendix D). Within each field, five catenary sequences were selected. In the forage fields, each catena consisted of a summit, midslope and lower slope position. In the wheat fields, four sites were selected down each slope. The summit position sampled was either an Orthic Regosol (eroded knoll) or a Chernozemic Calcareous Brown. The midslope positions were either Calcareous or Orthic Brown and the lower slope profile was a more moist Orthic or a Cumulic Eluviated Brown. Each site was sampled for spring moisture and nutrient status. This was done immediately after seeding on the wheat fields. Growing season rainfall was recorded by each farmer. Where the forage fields were being grazed, cages were used to cover each plot.

At each site, yields were obtained by square yard sampling. The forage plots were harvested in June; the wheat fields were harvested in August just prior to swathing. Personnel from the Swift Current Research Station harvested the forage plots, dried and weighed both wheat and forage samples, and analyzed the forage for protein content and the wheat for both protein and phosphorus content.

RESULTS AND DISCUSSION

All results reported are from data obtained in 1973.

Forage Productivity Study

Available soil phosphorus was highest at the lower slope Orthic and Eluviated sites (Table 4.1). The dark colored Ah horizons of these profiles were quite thick, largely due to translocation of surface material downslope by wind and water.

Table 4.1 Available soil phosphorus (lb/acre, 0-6 in) for all forage fields.

		Mean	Range	Standard Error
Summit	Regosol	6	2-15	0.8
	Calcareous	10	8-13	0.9
Midslope	Calcareous	9	4-25	3.9
	Orthic	10	2-22	1.1
Lower slope	Orthic	19	7-94	4.5
	Eluviated	15	4-27	4.9

Table 4.2 Available soil nitrogen (lb/acre, 0-24 in) for all forage fields.

		Mean	Range	Standard Error
Summit	Regosol	18	8-63	4.1
	Calcareous	20	8-49	7.5
Midslope	Calcareous	13	10-17	1.1
	Orthic	14	8-33	1.6
Lower slope	Orthic	16	8-32	1.3
	Eluviated	18	10-43	6.2

Table 4.3 Available soil potassium (lb/acre, 0-6 in) for all forage fields.

		Mean	Range	Standard Error
Summit	Regosol	470	215-870	42
	Calcareous	450	220-680	92
Midslope	Calcareous	490	265-680	67
	Orthic	440	200-725	34
Lower slope	Orthic	680	320-900	38
	Eluviated	790	570-900	59

The phosphorus content of the midslope Calcareous and Orthic profiles and the summit Calcareous profiles were all about equal, but as expected, the Orthic Regosol profiles on the knoll contained significantly lower amounts of phosphorus.

The available soil nitrogen was similar for all profiles on all sites, ranging from 13 to 20 lb/acre (Table 4.2). These levels are all considered low to very low by soil testing standards. Where the forage was a grass-alfalfa mixture, it would be recommended that an additional 15 to 30 lb/acre of fertilizer N be applied; where it was grass alone, an additional 60 to 70 lb/acre of fertilizer N would be required.

Available soil potassium was in excess for all profiles in all slope positions (Table 4.3). There was a marked increase in the lower slope position, attributed mainly to translocation of surface materials downslope.

The available soil moisture to a two foot depth increased from a low of 2.4 inches in the two profiles on the summit to a high of 3.1 inches in the two lower slope profiles (Table 4.4). The wide variation between summit and lower slope moisture contents found in other years was not found in 1973 due to good rainfall in early April.

The highest forage yield (0.9 ton/acre) was obtained from the lower slope Orthic profile (Table 4.5). The midslope Calcareous and lower slope Eluviated profiles yielded 0.8 ton/acre and the midslope Orthic profile, 0.7 ton/acre. The lowest yields (0.5 ton/acre) were recorded from the Orthic Regosol and Calcareous profiles in the summit slope position. Forage protein percentages ranged from a low of 9.7% from the summit Calcareous profile

Table 4.4 Available water (inches to 2 feet) for all forage fields.

		Mean	Range	Standard Error
Summit	Regosol	2.4	1.3-3.7	0.1
	Calcareous	2.4	1.4-3.4	0.3
Midslope	Calcareous	2.7	2.0-4.2	0.4
	Orthic	2.4	1.6-4.2	0.2
Lower slope	Orthic	3.1	1.5-5.6	0.2
	Eluviated	3.1	2.2-3.7	0.3

Table 4.5 Forage yield (tons/acre, dry weight) for all forage fields.

		Mean	Range	Standard Error
Summit	Regosol	0.5	0.2-1.3	0.1
	Calcareous	0.5	0.2-0.9	0.1
Midslope	Calcareous	0.8	0.4-1.5	0.2
	Orthic	0.7	0.3-1.5	0.1
Lower slope	Orthic	0.9	0.2-1.8	0.1
	Eluviated	0.8	0.3-1.4	0.2

Table 4.6 Forage protein content (%) for all forage fields.

		Mean	Range	Standard Error
Summit	Regosol	10.5	8.3-13.4	0.4
	Calcareous	9.7	7.4-13.9	1.2
Midslope	Calcareous	9.8	8.9-12.7	0.7
	Orthic	9.9	7.8-14.1	0.4
Lower slope	Orthic	11.0	8.8-14.5	0.4
	Eluviated	10.5	8.9-11.2	0.4

(Table 4.6) to a high of 11.0% from the lower slope Orthic profile.

Wheat Productivity Study

Available soil phosphorus increased with increasing profile development down the slope (Table 4.7). The Orthic Regosol profile from the summit position contained the lowest amount of available phosphorus (9 lb/acre) and the Orthic profile from the lower slope position contained the highest amount (39 lb/acre). The increase downslope is largely attributed to the increasing thickness of the Ah horizon which increased from 3 to 4 inches thick on the knolls, to 4 to 8 inches thick in the midslope positions, to 10 to 14 inches thick in the lower slope position. The thick Ah in the lower slope position is partially attributed to colluvial buildup by wind and water. Soil test recommendations indicate that an additional 30 lb/acre P_2O_5 would be required to supplement the low phosphorus content of the Orthic Regosol and upper midslope Calcareous and Orthic profiles, and 20 lb/acre to supplement the phosphorus supply of the Orthic profile in the lower midslope position. No additional phosphorus would be required for the soil profiles in the lower slope position.

Available soil nitrogen increased from a low of 42 lb/acre for the Orthic Regosol profile from the summit position to a high of 96 lb/acre for the Orthic profile in the lower slope position (Table 4.8). The high available nitrogen in the lower slope position is attributed to nutrient leaching and translocation of surface materials downslope by wind and water. Nitrogen is measured to a depth of 24 inches and in some cases the dark colored surface horizons were almost that thick. No additional

Table 4.7 Available soil phosphorus (lb/acre, 0-6 in) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	9	5-13	0.6
Upper midslope	Calcareous	10	4-33	1.7
	Orthic	10	6-13	1.4
Lower midslope	Orthic	16	6-27	1.3
Lower slope	Orthic	39	33-50	3.7
	Eluviated	37	8-68	4.1

Table 4.8 Available soil nitrogen (lb/acre, 0-24 in) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	42	21- 61	2.5
Upper midslope	Calcareous	47	10- 88	6.6
	Orthic	54	30- 72	8.8
Lower midslope	Orthic	65	12-102	6.9
Lower slope	Orthic	96	49-154	21.8
	Eluviated	93	39-190	8.9

nitrogen would be required in the form of fertilizer. The nitrogen values for the wheat fields are all higher than those reported for the forage sites due to a significant nutrient buildup during the summerfallow year.

Available soil potassium was in excess for all profiles in all slope positions (Table 4.9). The large potassium increase in the lower slope position is attributed mainly to translocation of surface materials downslope.

The available soil moisture to a two foot depth ranged from 2.8 to 3.9 inches, the highest amount occurring in the Eluviated profile (Table 4.10). All values were slightly higher than those reported for the forage fields, due mainly to moisture storage over the summerfallow year.

From this discussion of soil nutrient and moisture levels, it would be expected that the grain yield should increase from summit to lower slope positions. This expected trend is illustrated in Table 4.11, where it can be seen that the yield ranged from a low of 17.7 bu/acre on the shallow Orthic Regosol to a high of 36.7 bu/acre on the lower slope Orthic profile. Straw yield also increased down the slope (Table 4.12).

The percentage phosphorus in the grain increased slightly downslope (Table 4.13), as did the protein content of the grain (Table 4.14). The grain protein content was slightly higher than that found in 1972.

CONCLUSION

This study has been continued for three consecutive years, 1971 to 1973. Each year the results have followed the same general trend and the variations in yield, nutrient levels, and

Table 4.9 Available soil potassium (lb/acre, 0-6 in) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	440	240-545	17.9
Upper midslope	Calcareous	365	245-515	24.5
	Orthic	310	215-460	55.2
Lower midslope	Orthic	415	190-810	33.2
Lower slope	Orthic	610	445-810	89.9
	Eluviated	610	370-900	44.1

Table 4.10 Available water (inches to 2 feet) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	3.3	1.6-4.3	0.2
Upper midslope	Calcareous	3.5	2.4-4.5	0.1
	Orthic	3.5	3.3-3.9	0.2
Lower midslope	Orthic	2.8	2.1-3.4	0.1
Lower slope	Orthic	3.3	2.3-4.4	1.1
	Eluviated	3.9	2.4-5.7	0.3

Table 4.11 Grain yield (bu/acre) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	17.7	8.9-23.0	
Upper midslope	Calcareous	20.6	8.8-28.3	
	Orthic	19.3	15.6-21.2	
Lower midslope	Orthic	28.5	17.1-37.1	
Lower slope	Orthic	36.7	27.8-45.6	
	Eluviated	33.5	12.8-47.6	

Table 4.12 Straw yield (CWT/acre) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	11.7	6.6-15.1	
Upper midslope	Calcareous	13.2	6.2-17.3	
	Orthic	12.1	10.2-13.1	
Lower midslope	Orthic	18.2	11.5-23.3	
Lower slope	Orthic	19.5	6.9-32.1	
	Eluviated	25.1	11.1-35.4	

Table 4.13 Grain phosphorus content (%) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	0.25	0.20-0.30	0.01
Upper midslope	Calcareous	0.25	0.20-0.31	0.01
	Orthic	0.24	0.22-0.26	0.01
Lower midslope	Orthic	0.27	0.17-0.38	0.01
Lower slope	Orthic	0.34	0.29-0.39	0.05
	Eluviated	0.31	0.21-0.42	0.02

Table 4.14 Grain protein content (%) for all wheat fields.

		Mean	Range	Standard Error
Summit	Regosol	12.8	10.7-14.6	0.3
Upper midslope	Calcareous	12.8	10.3-14.6	0.4
	Orthic	13.9	13.5-14.4	0.3
Lower midslope	Orthic	14.0	12.5-16.3	0.3
Lower slope	Orthic	13.9	13.2-14.6	0.7
	Eluviated	14.5	13.0-16.6	0.3

moisture status between Orthic Regosol, Calcareous, Orthic and Cumulic Eluviated soil series of the Haverhill Association provide adequate data to evaluate and substantiate some of the separations presently being made on the new soil maps. This study will not be continued in the Swift Current area in 1974.

5. APPENDICES

Appendix A. Legal location and soil type of experimental field plots for 1973 irrigation trials.

Farmer Cooperator	Crop Investigated	Legal Location	Soil Type
G. Anderson	Barley	SE4-28-7-W3	Elstow:loam
	Soft Wheat		
	Rapeseed		
B. Davison	Barley	SW34-29-8-W3	Asquith:v.l.
	Soft Wheat		
	Rapeseed		
M. Cameron	Corn	NW27-29-8-W3	Asquith:f.l.
A. Carlson	Barley	SW13-27-7-W3	Elstow:loam
	Soft Wheat	NE14-27-7-W3	Elstow:loam
K. Carlson	Rapeseed	SE27-30-7-W3	Bradwell:v.l.
H. Martyn	Corn	NE9-28-7-W3	Elstow:loam
B. Niska	Soft Wheat	NE22-27-7-W3	Bradwell:v.l.
	Rapeseed	NW23-27-7-W3	Elstow:loam
L. Pederson	Barley	SE20-28-7-W3	Elstow:loam
	Soft Wheat	SE20-28-7-W3	Elstow:loam
	Rapeseed	SW20-28-7-W3	Elstow:loam
A. Pederson	Corn	SW21-28-7-W3	Elstow:loam
A. Stranden	Barley	NE6-31-7-W3	Elstow:loam
Vestre Bros.	Alfalfa	NE32-27-7-W3	Elstow:loam (A horizon Removed)
R. Ziegler	Alfalfa	NE21-28-7-W3	Elstow:loam

Appendix B. Legal location and soil type of experimental field plots for 1973 nitrogen trials.

Farmer Cooperator	Crop Investigated	Legal Location	Soil Type
E. Peters	Barley	NW13-43-5-W3	Blaine Lake:Sicl
	Wheat		

Appendix C. Legal location and soil type of experimental field plots for 1973 fababean trials.

Farmer Cooperator	Crop Investigated	Legal Location	Soil Type
E. Peters	Fababeans on summerfallow	SW24-43-5-W3	Blaine Lake:Sicl
	Fababeans on stubble	NW24-43-5-W3	Blaine Lake:Sicl

Appendix D. Legal locations of co-operating farmers in soil productivity study.

Farmer	Legal Location
Forage fields:	
M. Arnold, Shamrock	NE4-15-5-W3
M. Moore, Chaplin	E½33-15-6-W3
G. Fech, Morse	NW27-17-8-W3
H. Wentland, Waldeck	SW9-18-12-W3
J. Kazeil, Leinan	NW15-18-13-W3
Wheat fields:	
W. Glascock, Shamrock	SW2-15-5-W3
R. Gleim, Chaplin	SW34-15-6-W3
G. Fech, Morse	E½28-17-8-W3
D. Spady, Waldeck	N½9-18-12-W3
B. Moen, Leinan	SE15-18-13-W3

6.1 POTENTIAL YIELD OF CEREAL AND OILSEED CROPS ON STUBBLE LAND (by K.B. MacDonald)

INTRODUCTION

The practice of cropping and fallowing lands in alternate years has gained wide acceptance throughout the prairies, and particularly in Saskatchewan. One reason often cited for summerfallowing is that it provides a measure of insurance for a good yield of the subsequent crop.

Recent papers by Paul (1972) and Rennie (1973) have documented specific adverse effects of summerfallow, particularly when it appears in a rotation every other year, on the soil and its associated environment. Particular adverse effects cited include; rapid degradation and loss of active humus, the release of nitrogen in amounts in excess of crop requirements, the possible contamination of ground water by nitrogen leakage, and the incipient spread of salinity.

It is pertinent to consider whether there is a real physical basis for the large acreages of Saskatchewan crop land which are fallowed, or whether the practice of fallowing is primarily one of tradition. Of particular relevance is the question of why cropping practices remain relatively constant across the entire agricultural area of the province while:

(1) soils range from brown to dark brown, to black to gray, reflecting soil formation under conditions of different moisture and temperature,

(2) seasonal rainfall (May 10 to August 7 for example) ranges from 4 inches in the southwest part of the province to about 7.8 inches in the northeast area of the agricultural district.

(3) ARDA classes of climatic limitation range from 1 (no significant moisture limitation) to 3 (moderately severe moisture limitations).

Why is this climatic and soil variation not reflected in differences in cropping practices?

This study was initiated to evaluate, as far as possible and within the funds available, existing data on the yield of food crops on stubble land in Saskatchewan and to document the significance of deterrents to seeding stubble land, namely the significance and probability of lack of moisture or droughts, weed infestations, seedbed preparation and optimum crop sequences for specific soil and climatic regions.

The practical implications of this study are an estimation of the potential yield of crops seeded on stubble land. Since world carryover of grain is the lowest in 25 years and it appears likely that the situation of favorable demand and price will persist, it is appropriate to assess the type of farm management practices required to make stubble cropping an attractive proposition.

<u>Yield and Climatic Data and its Sources</u>

Previous studies (Williams, 1973; Williams, 1971; and Williams and Robertson, 1964) have attempted to relate crop production on the prairies to climatic information. These studies have dealt exclusively with wheat and have not differentiated between crop grown on stubble and crop grown on fallow. They have assumed one level of management and dealt with the entire Canadian wheat growing district. They were therefore fairly general. Data on the yield of crops summarized on the basis of yields on stubble land and on fallow land has, until recently, been limited. The economics of wheat yields on stubble land have been assessed (Baier, 1970) for southern Saskatchewan. This study was restricted to the Brown soil zone and relied heavily on data from the Swift Current Research Station. Crops grown on stubble land have fertility requirements different from those on fallow. This factor which implies that the yield of crops grown on stubble land may be restricted by nutrient levels as well as limited moisture was not considered.

Since 1964 the Dominion Bureau of Statistics (DBS) has collected information, on a crop district basis, of the yields of wheat, oats, barley, flax, and rapeseed. This data has been summarized as yields of these crops on fallow and on stubble, as well as the respective acreages of the crops seeded. From these data the change in cropping practices from one part of the province to another can be calculated. Table 1 shows the 9-year average of the cropping patterns as compiled by the DBS. While there is some variation in cropping patterns across the province, it is fairly slight. The ratio of the acreage of stubble crop to total seeded acreage varies from 0.14 up to 0.41. This represents management practices where from 8 to 26% of the cropped land is seeded on stubble or from 37 to 46% of the cultivated acreage is fallowed in any one year. It is apparent then, that throughout the province the general practice is a 2-year rotation, and that stubble cropping and longer crop rotations play only a very minor role in the overall cropping practices in Saskatchewan.

This project was initiated with a view to determining whether the limited acreages of stubble crop were due to real physical limitations caused by climate or environmental conditions, due to tradition, or due to the market situation.

In selecting an approach to this problem it was decided to look at the physical model first with particular emphasis on the

Table 1. Cropping practices in Saskatchewan - average for 9-year period 1964-1972.

Crop District	Average acreage seeded per year			Ratio of acreage seeded on stubble to total seeded acreage
	Total	on Fallow	on Stubble	
	(in thousands of acres)			
1A	1045.0	738.4	306.6	0.29
1B	801.2	574.6	226.6	0.28
2A	910.7	709.0	201.7	0.22
2B	1330.0	991.3	338.7	0.25
3AN	714.3	604.6	109.7	0.15
3AS	1317.0	1104.8	212.2	0.16
3BN	1326.0	1090.2	235.8	0.18
3BS	940.2	795.2	145.0	0.15
4A	504.5	412.2	92.3	0.18
4B	722.6	620.8	101.8	0.14
5A	1432.3	1042.5	389.8	0.27
5B	1666.7	1089.3	577.4	0.35
6A	1815.2	1398.1	417.1	0.23
6B	1441.4	1072.9	368.5	0.26
7A	1327.8	1081.8	246.0	0.19
7B	1053.9	798.3	255.6	0.24
8A	992.4	646.3	346.1	0.35
8B	1171.4	690.0	481.4	0.41
9A	1446.7	935.6	511.1	0.35
9B	968.7	675.4	293.3	0.30

climatic limitations. In order to restrict the volume of analysis, the first step was to determine which of the crop yields recorded showed similar variations with time and environmental conditions. Simple linear correlations were run between all crops for all crop districts in Saskatchewan for the years 1964 to 1972 inclusive (Table 2). From these comparisons it was readily apparent that the three cereals, wheat, oats, and barley, behaved similarly to each other whether grown on stubble or fallow land (minimum r value obtained between yields of cereals was 0.88 between wheat grown on fallow and barley grown on stubble). It is quite apparent however, that rapeseed and flax responded to the environmental conditions quite differently than cereals and also differently to each other (Table 2, Table 3).

On the basis of these yield correlations it was decided to look at the effects of various climatic conditions on the yields of wheat, rapeseed, flax.

Climatic data from across the province were selected[1]. Twelve meteorological stations were selected as having reasonably reliable long-term records, and being representative of the broad climatic regions of the province. The climatic stations used and the number of years of records available are listed in Table 4. Also included in this table is the crop district in which these stations occur. Long-term summaries of climatic trends were made for the 30-year period 1941-1970 or shorter where complete records were not available. The crop districts

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[1]The advice and assistance of Dr. J.L. Bergsteinsson of the Saskatchewan Research Council in selecting appropriate meteorological stations and in summarizing the climatic data is greatly appreciated.

Table 2. Correlation coefficients for yields of various crops in all crop districts in Saskatchewan for the 9-year period 1964-1972.

	Fallow				Stubble			
	Wheat	Oats	Barley	Flax	Wheat	Oats	Barley	Flax
A) Fallow								
Wheat	1.00	0.90	0.93	0.76	0.92	0.87	0.88	0.72
Oats		1.00	0.95	0.79	0.90	0.95	0.91	0.75
Barley			1.00	0.80	0.91	0.92	0.94	0.77
Flax				1.00	0.75	0.78	0.78	0.78
B) Stubble								
Wheat					1.00	0.92	0.93	0.75
Oats						1.00	0.94	0.77
Barley							1.00	0.77
Flax								1.00

Table 3. Correlation coefficients for yields of wheat, rapeseed and flax for Saskatchewan crop districts 5-9 inclusive for the 9-year period 1964-1972.

	Fallow			Stubble		
	Wheat	Flax	Rapeseed	Wheat	Flax	Rapeseed
A) Fallow						
Wheat	1.00	0.76	0.66	0.93	0.63	0.41
Flax		1.00	0.42	0.69	0.50	0.27
Rapeseed			1.00	0.63	0.40	0.52
B) Stubble						
Wheat				1.00	0.66	0.38
Flax					1.00	0.14
Rapeseed						1.00

Table 4. Meteorological stations, crop district, soil zone and years of records.

Meteorological Station	Soil Zone	Crop District[3]	Number of years of records
Nashlyn	Brown	4A	26
Swift Current	Brown	3B-N	30
Kindersley	Brown	7A	26
Estevan	Dark Brown	1A	24
Regina	Dark Brown	2B	30
Saskatoon	Dark Brown	6B	30
Indian Head[1]	Black	2B	30
Yorkton	Thick Black	5A	29
Prince Albert	Black and Gray (Wooded)	9A	30
North Battleford[2]	Black	9A + 9B	30
Hudson Bay	Gray (Wooded) and Black	8A	27
Waseca[2]	Black	9B	25

[1]Records from this station were not used in subsequent analysis.

[2]Data from these stations were combined to give an estimate of climate in crop district 9B.

[3]These crop district and meteorological station pairs form the data base used in the subsequent analysis.

of Saskatchewan are shown on Figure 1 along with the soil zones and the selected climatic stations.

To determine the effects of climate on crop yields, regression analysis was carried out using various meteorological parameters. The parameters recorded for each weather station and their abbreviations are summarized in Table 5.

One of the major problems inherent in this type of study is in obtaining reliable and useful data. It must be realized that the yield figures collected by the DBS are estimates over the relatively large area of a crop district. The climatic information has been collected at a particular point location and strictly speaking applies only to a very localized area around the station.

It has been assumed (i) that the yield estimates obtained from the DBS are reasonably reliable and (ii) that the climatic data from each meteorological station can be generalized to give an index of climatic conditions over the crop district in which it occurs.

Multiple Regression Analysis

With the aid of a digital computer, unspecified stepwise multiple regression analysis was carried out using crop yields as the dependent variable and the various climatic parameters listed in Table 5 as independent variables. In this analysis an equation is generated of the form:

$$Y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \ldots\ldots \text{ etc.}$$

where Y represents yield in bus/acre

a_0 is a constant

a_1, a_2, a_3 .... are the regression coefficients

and x_1, x_2, x_3 .... are the various independent variables.

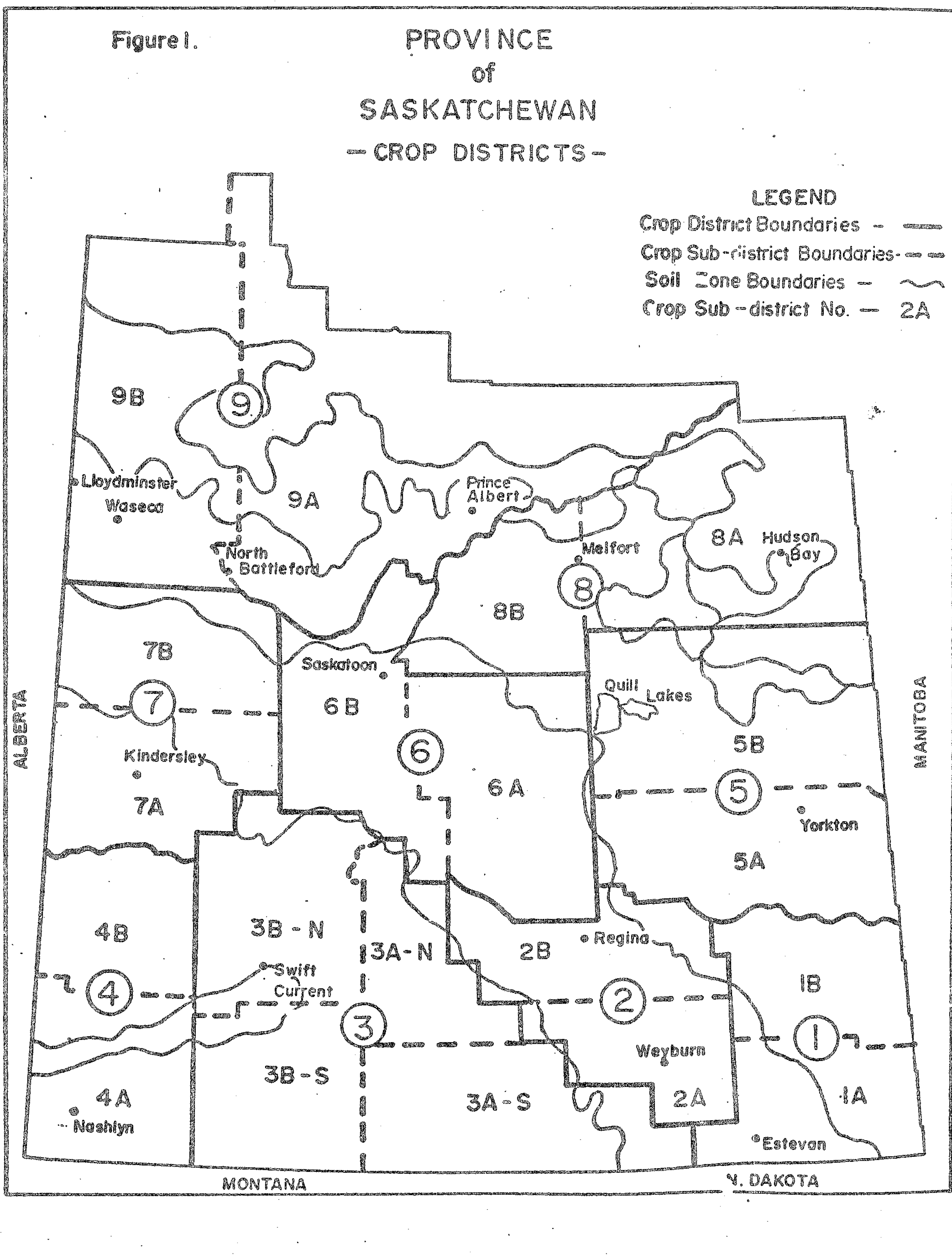
Figure l.
PROVINCE
of
SASKATCHEWAN
-CROP DISTRICTS-
LEGEND
Crop District Boundaries
Crop Sub-district Boundaries
Soil Zone Boundaries
Crop Sub-district No. — 2A
9B
9
9A
Lloydminster
Waseca
North Battleford
Prince Albert
8A
Hudson Bay
Melfort
8
8B
7B
7
Saskatoon
6B
6
6A
Quill Lakes
5B
5
Yorkton
5A
Kindersley
7A
ALBERTA
MANITOBA
4B
4
4A
Nashlyn
3B - N
3A-N
Swift Current
3
3B - S
3A - S
2B
Regina
2
Weyburn
2A
1B
1
1A
Estevan
MONTANA
N. DAKOTA

Table 5. Meteorological parameters used and their abbreviations.

1.	May GDD	Growing degree days above $42^{\circ}F$ for the month of May.
2.	June GDD	Growing degree days above $42^{\circ}F$ for the month of June.
3.	July GDD	Growing degree days above $42^{\circ}F$ for the month of July.
4.	August GDD	Growing degree days above $42^{\circ}F$ for the month of August.
5.	Freezeday	Day of previous fall when mean temperature over a 10-day period following the day was below $32^{\circ}F$.
6.	Meltday	Day of spring when mean temperature was above $32^{\circ}F$ for the 10-day period following.
7.	Season rain	Total rainfall over the growing season May 10 to August 7 (90 days).
8.	Nov-Apr 1	Precipitation from November 1 to April 30 of the winter prior to seeding.
9.	May-Oct 1	Precipitation from May 1 to October 31 of the summer prior to seeding.
10.	Nov-Apr 2	Precipitation from November 1 to April 30 of the winter prior to the summer of fallow.
11.	Aug-Oct 2	Precipitation from August 1 to October 31 of the summer of the last crop for fallow, i.e. 2 years prior to the crop seeded on fallow.
12.	Aug-Oct 1	Precipitation from August 1 to October 31 of the summer of the last crop for stubble, i.e. the fall prior to seeding.
13.	Drought	The total number of days occurring during stress periods throughout the growing season.
14.	Period 1	The total number of days occurring during stress periods from May 15 to June 15.
15.	Period 3	The total number of days occurring during stress periods from June 15 to July 15.
16.	Period 5	The total number of days occurring during stress periods from July 15 to August 15.
17.	MUI	Moisture Use Index - an estimate of the actual water use to potential water use, estimated from precipitation and season growing degree days above $42^{\circ}F$.

The independent variables are brought into the equation one at a time. They are included in such an order that a variable brought into the equation explains less of the yield variation than any variable already in the equation and more than any variable yet to be included. Consequently, the order of inclusion gives some indication of the relative importance of the various parameters. At each step of the regression a multiple correlation coefficient can be calculated to indicate the degree of correlation achieved.

The order of variable inclusion for the first five steps and the correlation coefficient obtained at the fifth step are summarized in Table 6. These results show that for wheat yields, across the province and by soil zone, rainfall during the growing season is the most important climatic variable, with the exception of the yield of fallow wheat in the Black and Parkland soil zone.

One trend which is apparent from this analysis is that for wheat seeded on stubble land, drought or moisture stress early in the growing season appears to be an important factor limiting yields, also growing degree days above 42°F in May and June appear to have relatively important effects on yields.

Rapeseed yields were less correlated with climatic variables than were wheat yields. Also, in comparison to wheat, they were more closely related to variables other than growing season precipitation.

A similar analysis for flax has not yet been carried out. When this analysis is completed a more detailed interpretation of the results for all crops will be carried out.

Table 6. Order of inclusion of climatic variables in stepwise regression analysis Multiple linear regression.

	First Variable	Second Variable	Third Variable	Fourth Variable	Fifth Variable	Multiple Corr. Coeff.	R^2
<u>Province</u>							
Wheat on Fallow	Season rain	Aug-Oct 2	May GDD	June GDD	Drought	0.76	0.57
Wheat on Stubble	Season rain	Period 1	May GDD	Aug-Oct 1	Periods	0.72	0.52
<u>Brown Soil Zone</u>							
Wheat on Fallow	Season rain	May GDD	Period 5	Aug-Oct 1	Nov-Apr 1	0.84	0.70
Wheat on Stubble	Season rain	May GDD	Aug-Oct 1	Period 5	Drought	0.82	0.67
<u>Dark Brown Soil Zone</u>							
Wheat on Fallow	Season rain	Nov-Apr 2	June GDD	Aug-Oct 2	May-Oct 1	0.82	0.68
Wheat on Stubble	Season rain	Period 1	May GDD	Period 5	Freezeday	0.69	0.48
<u>Black and Parkland Soil Zone</u>							
Wheat on Fallow	Period 1	Aug-Oct 2	May GDD	June GDD	Season rain	0.83	0.69
Wheat on Stubble	Season rain	Period 1	Meltday	May GDD	June GDD	0.81	0.66
Rapeseed on Fallow	Period 1	Aug-Oct 1	Nov-Apr 1	Aug-Oct 2	Drought	0.77	0.59
Rapeseed on Stubble	Aug GDD	Period 1	June GDD	Period 5	Aug-Oct 1	0.79	0.62

Affect of Moisture on Crop Production

One of the commonly stated reasons for summerfallowing land is to increase the levels of moisture stored in the soil at seeding time. While the actual efficiency of moisture storage during the fallow period is somewhat controversial it is generally agreed that some moisture is conserved.

An attempt was made to determine to what extent crop yields could be explained using only precipitation information. An integral part of this endeavor was the attempt to determine whether the difference in moisture over the fallow period would explain all the difference in yield observed between stubble and fallow crops.

Stepwise multiple regression analysis was carried out to relate the yields of wheat, rapeseed, and flax to the amount of precipitation during the growing season and during the period from the previous harvest to seeding. For fallow seeding crops the independent variables in the analysis were SEASONRAIN, NOVAPR 1, MAYOCT 1, NOVAPR 2, and AUGOCT 2 and for fallow the moisture variables were SEASONRAIN, NOVAPR 1, and AUGOCT 1.

The results of these analyses are tabulated in Table 7. The yields of wheat grown on fallow were highly correlated ($r = 0.82$ and 0.80 for fallow wheat in the Brown and Dark Brown soil zones respectively) with precipitation. As for the yields of wheat grown on stubble ($r = 0.74$ for stubble wheat in the Brown and Dark Brown soil zones).

In the Black and Parkland soil zone the correlation between wheat yield and precipitation was much lower ($r = 0.52$ for wheat grown on fallow and $r = 0.57$ for wheat grown on stubble). This

Table 7. Coefficients from stepwise multiple regression using precipitation variables.

Crop	Season Rain	Nov-Apr 1	Aug-Oct 1	May-Oct 1	Nov-Apr 2	Aug-Oct 2	Constant	Corr. Coeff	R^2
Province									
Wheat-Fallow	1.17	- .55		0.50	-0.33	0.93	13.04	0.69	0.48
Wheat-Stubble	1.17	n.s.[1]	0.57				7.18	0.68	0.46
Flax-Fallow	0.72	-0.44		0.09	-0.10	0.36	10.07	0.53	0.29
Flax-Stubble	0.63	0.08	0.20				4.85	0.57	0.33
Brown Soil Zone									
Wheat-Fallow	1.60	-1.25		1.01	0.41	1.04	6.52	0.82	0.67
Wheat-Stubble	1.67	-0.33	1.09				4.35	0.74	0.55
Dark Brown Soil Zone									
Wheat-Fallow	1.08	0.45		0.11	-2.44	0.64	21.77	0.80	0.65
Wheat-Stubble	1.20	0.45	1.04				2.58	0.74	0.54
Black and Parkland Soil Zone									
Wheat-Fallow	0.79	- .25		0.31	- .28	0.74	17.07	0.52	0.27
Wheat-Stubble	0.87	n.s.	0.18				10.97	0.57	0.32
Crop Districts[2] 5A, 6B, 7A, 8A, 9A, 9B									
Wheat-Fallow	0.94	-0.75		0.32	n.s.	1.08	16.27	0.62	0.39
Wheat-Stubble	1.09	-0.57	0.38				12.25	0.61	0.37
Rapeseed-Fallow	0.19	0.41		0.02	0.09	0.21	14.47	0.41	0.17
Rapeseed-Stubble	0.62	-0.22	-0.15				10.21	0.40	0.16
Flax-Fallow	0.70	-0.80		0.25	-0.20	0.11	12.28	0.50	0.25
Flax-Stubble	0.47	n.s.	0.35				6.15	0.52	0.28

[1] n.s. = not significant at the p = 0.001 level.

[2] Rapeseed yields are reported on a crop district basis only for crop districts 5-9 inclusive. A similar analysis is included for wheat and flax for comparative purposes.

evidence suggests that moisture is not a major limiting factor in determining crop yields in these areas. It also points out that the extra moisture stored during the fallow season does not contribute greatly to improved crop yields. Relating this back to general cropping practices across the province, this observation suggests that the levels of fallow, while somewhat lower in the Black and Parkland region than in the other soil zones, should be reduced still further.

It has been suggested (de Jong and Rennie, 1967; de Wit, 1958) that, in a semi-arid climate such as the Great Plains region, dry matter production is directly proportional to the ratio of actual water use to potential water use. This relationship holds up to the point at which moisture no longer is the limiting factor.

With a view to testing this hypothesis in the yields of cereals and oilseed crops across the province it was decided to use season growing degree days above 42°F as an index of potential moisture use. While this is admittedly a crude approximation, it should reflect the differences in heat available for crop production and evapotranspiration across the province and to some extent the potential water use. This figure was converted to a relative value by dividing it by the average seasonal growing degree days above 42°F. Actual moisture use was approximated by taking the coefficients from the stepwise multiple regression (Table 7) times the amounts of precipitation in the corresponding periods. These coefficients will weight the various amounts of precipitation relative to each other according to the way they affect yield.

This gives a moisture use index of actual moisture use over potential moisture use (MUI) which reflects primarily the amount of moisture available to the crop and also accommodate some of the variation in heat from one area of the province to another and from one growing season to another. Using the regression coefficients over the whole province from Table 7 the result of the plot of wheat yield versus MUI is shown in Figure 2. Generally, the trend illustrated shows that wheat yield is strongly related to MUI at low values but as the MUI increases the yield becomes less dependent and tends to plateau. Trend lines have been sketched by eye for stubble yields and fallow yields. These follow the same line initially but tend to plateau at different levels. This is in keeping with the results reported by de Wit (1958) and also by de Jong and Rennie (1967), where yields plateauing at different levels represented differences in management or soil factors. If this interpretation is correct then the difference in management between stubble and fallow at the plateau level is equivalent to approximately 10-12 bushels of wheat per acre.

If proper management practices of stubble land can raise the level of the yield plateau then wheat yields grown on stubble will in general compare quite favorably with those on fallow. The risk of stubble cropping will, however, always be somewhat greater as illustrated by the lower yields on stubble land at low MUI. At least some of these low yields on stubble can be attributed to cases where precipitation from the previous harvest to seeding is low and hence the reserve of soil moisture at seeding time will also be low. This is a problem of management

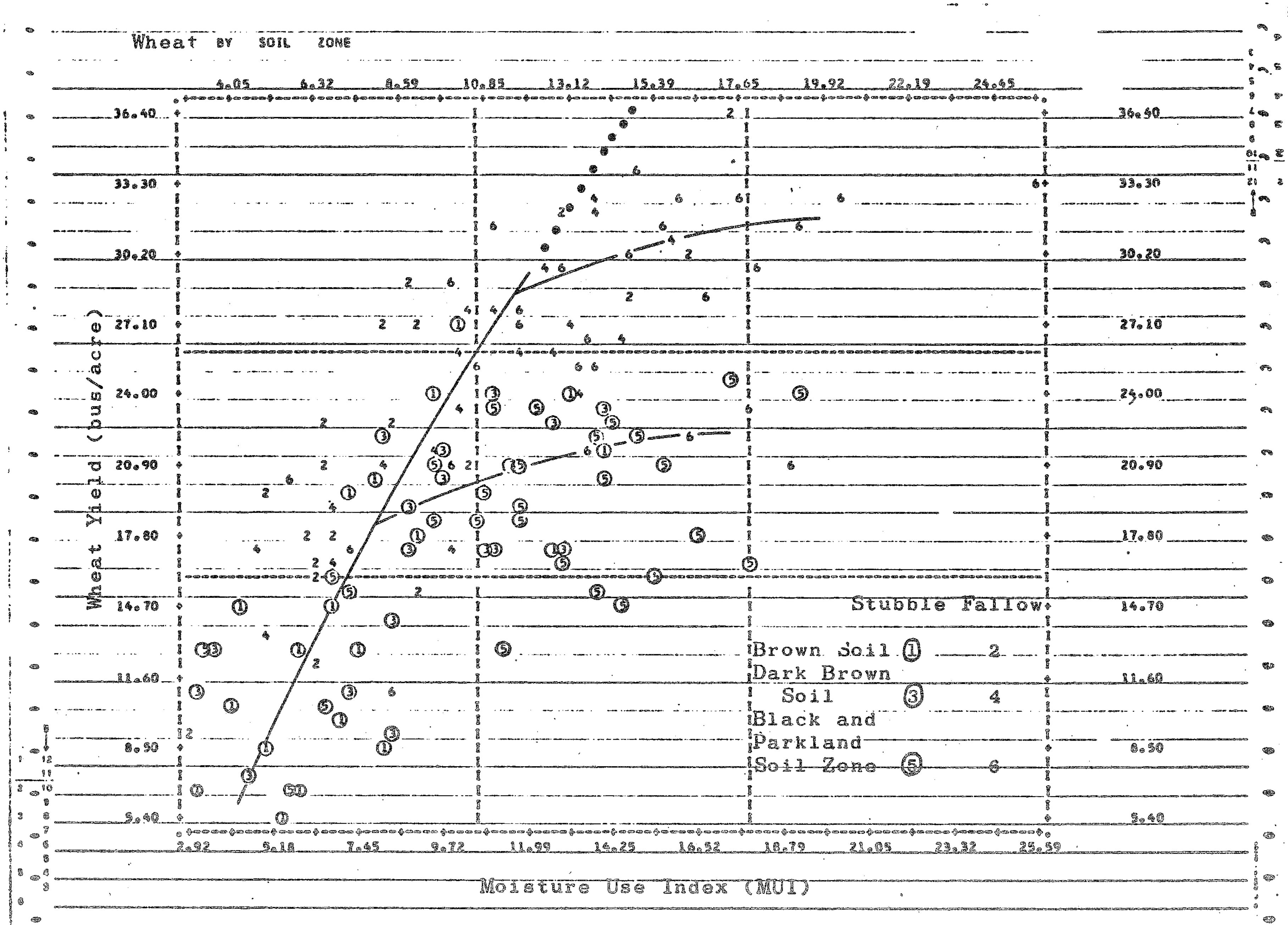

Figure 2. Yield of wheat across the province of Saskatchewan over the period 1964 to 1970 versus a calculated moisture use index. Trend lines have been ske.ched by .ye.

which can be overcome by determining the reserves of soil moisture prior to seeding and basing the seeding decision on this information.

Studies are now proceeding to:

(a) determine whether wheat plots fertilized up to optimum rates plateau at the same level as plots low in fertility, i.e. to determine whether proper plant nutrition can raise the potential yield levels of wheat seeded on stubble land.

(b) Check on the proportion of the low yields of wheat on stubble land (at a MUI of less than 10) which occur because of low amounts of precipitation from harvest of the previous crop to seeding. i.e. low levels of stored soil moisture in the spring, a problem which could be avoided by careful management.

The yields of flax grown on fallow and stubble are plotted against the MUI calculated for flax in the same way in which it was calculated for wheat. These results for flax yields across the province are illustrated in Figure 3. Flax yields show a weak relationship to MUI. The trends which were apparent were that the yields on stubble were approximately 7 bus/acre lower than on fallow. It seems likely that this difference in yields of flax on stubble land compared to fallow represent a management problem; possibly poor weed control, poor seedbed preparation, or low fertility levels. Austenson et al. (1970) suggest that poor weed control is a major factor limiting the yields of flax, especially when it is grown on stubble land.

Studies are now proceeding to determine whether other climatic factors such as drought, or high temperatures at particular times during the growing season, can explain part of the yield

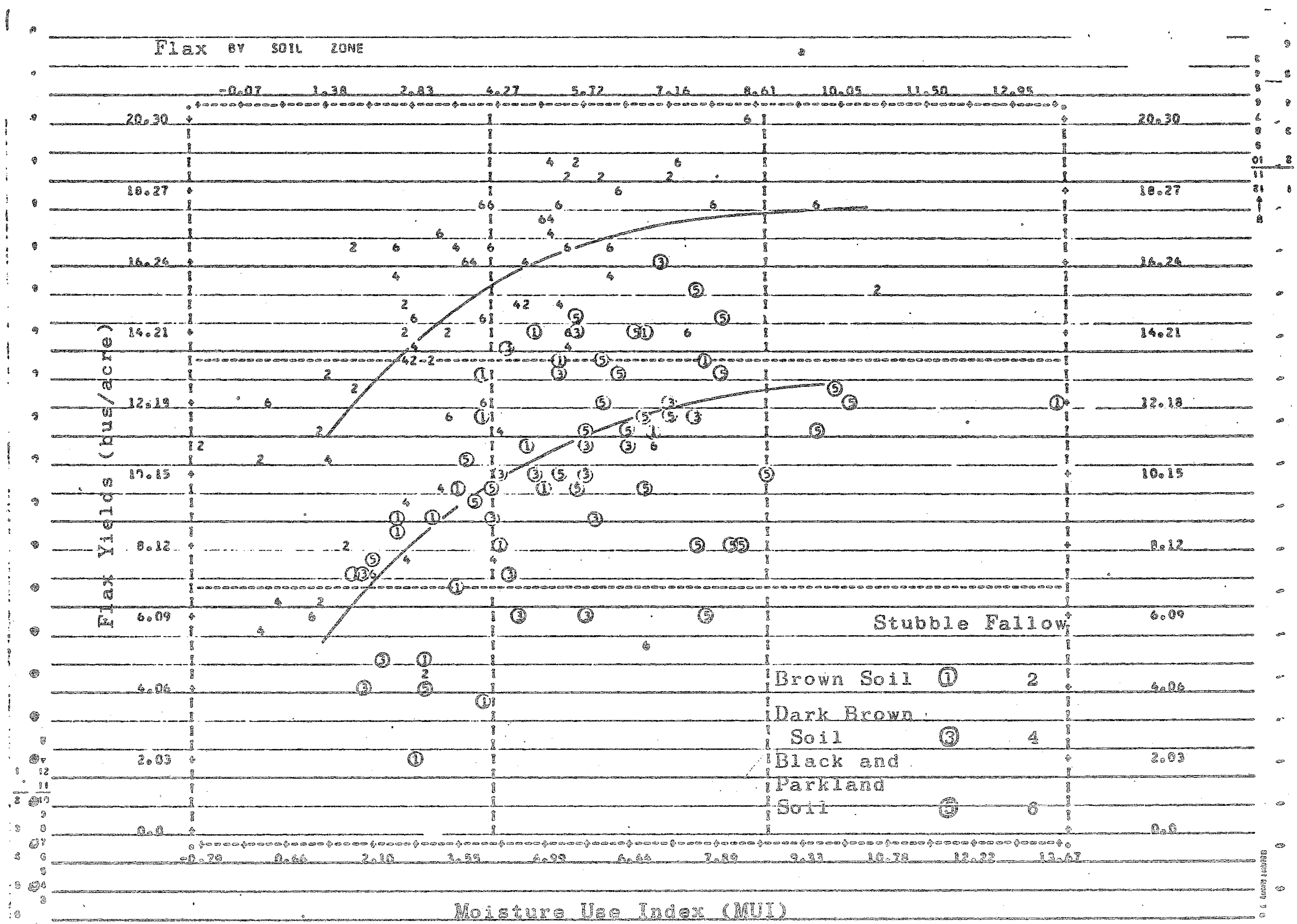

Figure 3. Yield of flax across the province of Saskatchewan over the period 1964 to 1970 versus a calculated moisture use index. Trend lines have been sketched by eye.

differences. It is doubtful whether sufficient research information on flax is available to isolate these aspects of management which most severely limit the potential yields of flax on stubble lands.

Yields of rapeseed on stubble and fallow have been collected on a crop district basis only for crop districts 5 to 9 inclusive. The MUI was determined for rapeseed and a plot of yield of rapeseed versus MUI is presented in Figure 4. The trend shown in this figure suggests that the yield of rapeseed on stubble lands is almost independent of the moisture use as expressed by the MUI, and has an average value of about 14 bus/acre. The yields of rapeseed on fallow land were more variable than yields on stubble, but again showed no apparent response to increasing MUI. They appear to be approximately 6 bus/acre higher than the stubble yields on the average.

It appears likely that part of the difference in yield of rapeseed on fallow and stubble may be due to differing fertility levels and differences in seedbed preparation. An attempt will be made to collect sufficient research data to confirm or deny these opinions. Also, other climatic parameters will be examined to determine what effect these may have on the yields of rapeseed on stubble and fallow.

For comparison the yields of wheat for crop districts 5 to 9 have been analyzed and an MUI calculated on the basis of these districts. These results are shown in Figure 5. It is obvious that the trend shown through wheat yields is similar to that seen over the whole province (Figure 2). Consequently, it seems likely that the trends observed for rapeseed represent a true

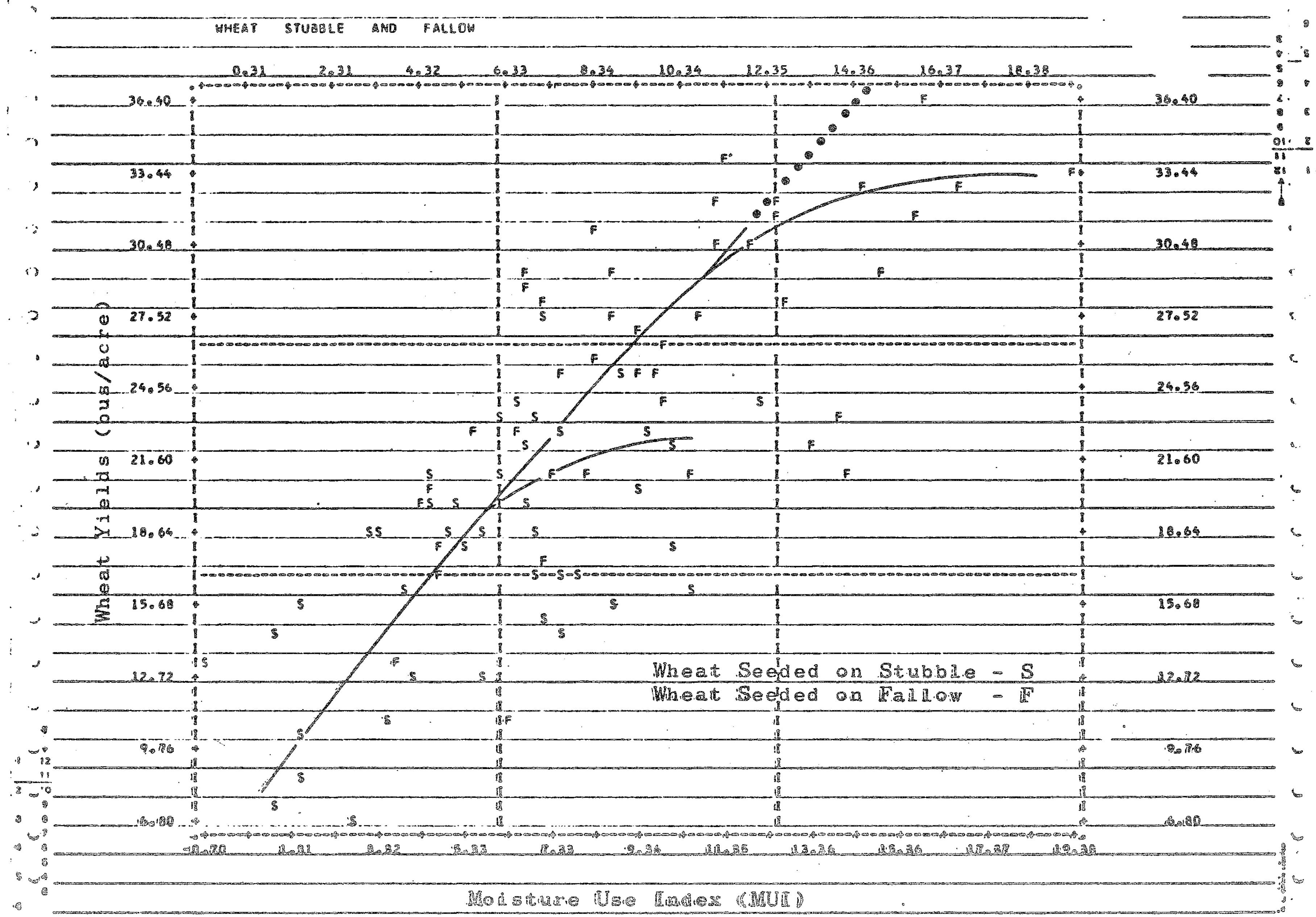

Figure 5. Yield of wheat in crop districts 5A, 6B, 7A, 8A, 9A, 9B of Saskatchewan for the period 1964 to 1970 versus a calculated moisture use index. Trend lines have been sketched by eye.

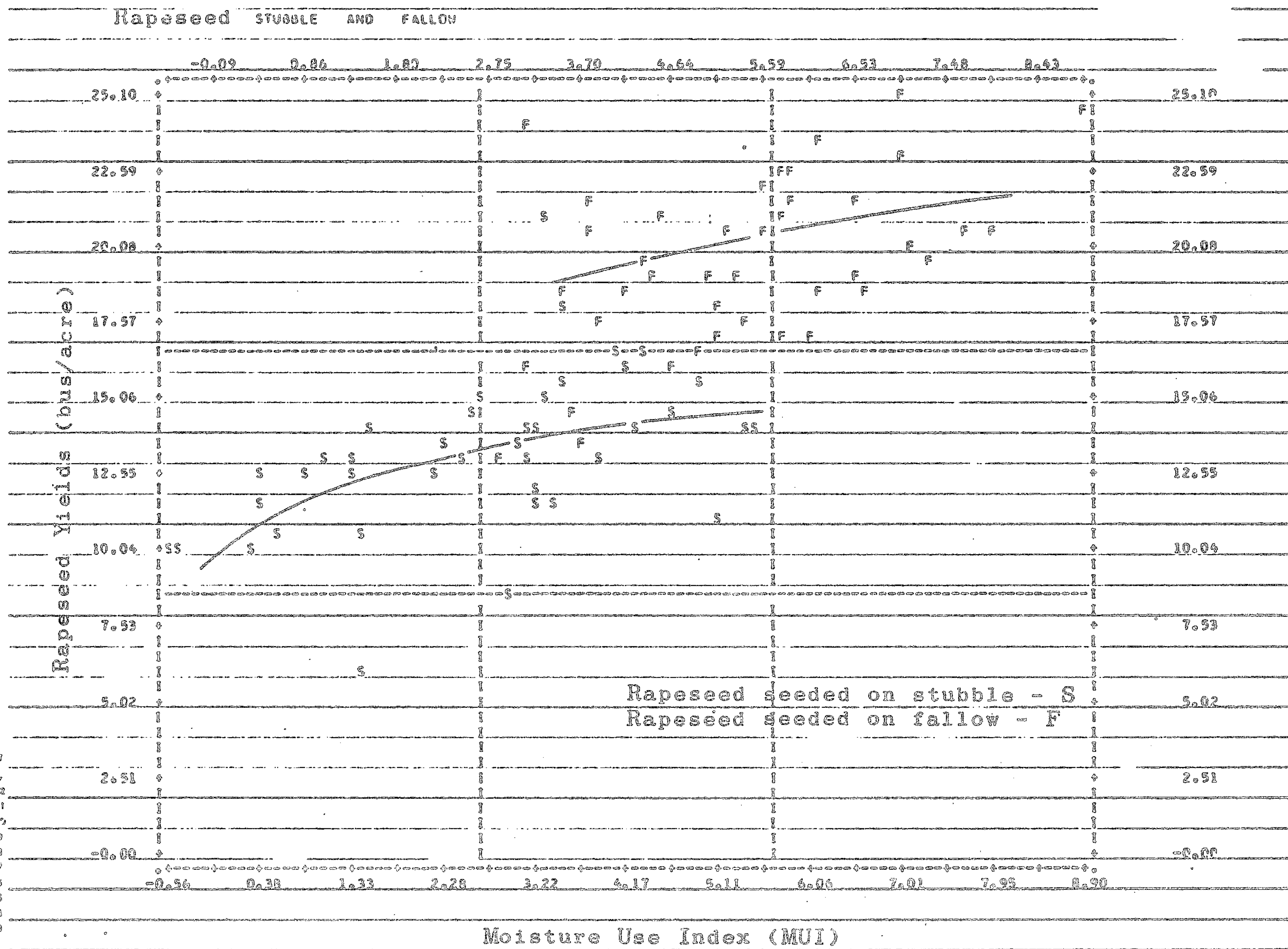

Figure 4. Yield of rapeseed in Saskatchewan crop districst 5A, 6B, 7A, 8A, 9A and 9B for the period 1964 to 1970 versus a calculated moisture use index. Trend lines have been sketched by eye.

crop response rather than simply a different data base.

The trends illustrated in Figure 2 are also apparent in this more limited set of data. The levelling off of the stubble yield is still apparent but less well defined. This could reflect less severe climatic limitations other than moisture or the fact that these data come from areas of the province where soil nitrogen levels are generally higher. If this latter is the case plant nutrient levels may be less of a limiting factor.

SUMMARY

The singular trend which is apparent in this study is that a lack of moisture on stubble lands is not the only factor restricting yields. While crops seeded on stubble land do appear to be somewhat more susceptible to periods of moisture stress, it also appears that management and possibly fertility levels may be important factors restricting the potential yields of stubble crops, especially of the oilseeds rapeseed and flax.

Prior to completion of this project, analysis will be carried out:

i) to expand the climatic data base by increasing the number of meteorological stations included,

ii) to complete the evaluation of various climatic variables for their effect on crop yields,

iii) to examine the relationship between crop yield and moisture at different levels of management, and

iv) a limited amount of analysis is proceeding to relate crop yields to various climatic parameters on an individual soil association basis. This will provide information on the effects of such variables as texture and slope class to yield under various environmental conditions.

It is hoped that this study will provide information on the benefits of various management practices. It will also point out some areas where further research is required to provide management guidelines for increasing the potential yields of crops, especially those grown on stubble lands.

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6.2 NITROGEN ISOTOPE RATIOS IN SURFACE AND SUB-SURFACE SOIL HORIZONS (by D.A. Rennie and E.A. Paul)

ABSTRACT

Nitrogen isotope analysis of surface soils and soil-derived nitrate for selected Chernozemic and Luvisolic soils showed mean $\partial\ ^{15}N$ values of 11.7 and 11.3 respectively. Isotope enrichment of the total N reached a maximum in the lower B horizon. Sub-soil parent material samples from the one deep profile included in the study indicated a $\partial\ ^{15}N$ value (NO_3-N) of 1/3 that of the Ap horizon, at a depth of 180 cm. The $\partial\ ^{15}N$ of sub-surface soil horizons containing residual fertilizer N were low (-2.2) compared to the surface horizon (9.9).

The data reported from this preliminary survey suggest that the natural variations in ^{15}N abundance between different soils and horizons of the same soil reflect the cumulative effects of soil genesis and soil management. More detailed knowledge and understanding of biological and other processes which control N isotope concentrations in these soils must be obtained before the data reported can be interpreted.

INTRODUCTION

Natural variations in ^{15}N abundance of a wide range of nitrogen-containing substances has been well established. Hauck (1973) listed some 20 different substances, including forest soils, coal, peat and pitchblend, etc. in which the per mil enrichment of ^{15}N compared to reference standards ranged from -13.0 to 953. Generally, however, the ^{15}N content of biosphere nitrogen is restricted to a range that frequently doesn't exceed ±10 $\partial\ ^{15}N$ units. While it has been recognized for some time that specific isotope effects occur (discrimination, exchange, etc.) as nitrogen moves through the biosphere cycle, there has been little interest shown in the natural variations in abundance of ^{15}N until Kohl et al. (1971) estimated the fertilizer N contribution to nitrate in surface waters of an Illinois corn belt watershed from measured differences in the isotope composition of soil N, atmospheric N, fertilizer N, and that of the nitrate in drainage waters. These workers assumed that, if all the nitrate in the waters was derived from the fertilizer, the ^{15}N abundance of the nitrate in the water would be the same as that of the fertilizer. If none of the nitrate was derived from the fertilizer, then the ^{15}N concentration would be the same as that of soil-derived nitrate. Intermediate values were assumed to reflect the fractional contribution of both sources. Several detailed and critical analyses of this approach have appeared in the literature (Hauck et al., 1972; Edwards, 1973; Hauck, 1973; Bremner and Tabatabai, 1973). However, as Hauck (1973) pointed out, there is a good reason to assume that variations in the natural abundance of ^{15}N <u>can</u> be used to obtain qualitative and perhaps semi-quantitative information on the broad relationships among N cycle processes under various environmental conditions. Whether such variations can be used for quantifying the effects of environmental changes on the nitrogen cycle over long-term or short-term periods must await an understanding of the isotope fractionation accompanying the nitrogen transformations in the soil-plant system.

A limited number of biologically induced isotope effects have already been reported. Biological discrimination against the heavier N isotope (^{15}N) occurs during the fixation of atmospheric N_2 by legume bacteria (Hoering, 1955; Delwiche and Steyn, 1970). Nitrogen isotope fractionation has been reported to occur during denitrification (Wellman et al., 1968) and during the oxidation of ammonia to nitrate (Delwiche and Steyn, 1970). Certain soil organisms which preferentially utilize NH_4 also discriminate against the heavier nitrogen isotope, with the result that the ammonia remaining in the media becomes enriched with respect to ^{15}N, providing, of course, assimilation is not completed.

The biologically induced isotope effects occurring in the soil should, under conditions of soil development, result in positive $\partial\ ^{15}N$ values, and this, in general, is reflected in the limited data reported in the literature (Cheng et al., 1964; Bremner et al., 1966; Delwiche and Steyn, 1970; Kohl et al., 1971; Feigin et al., 1974; Feigin et al., 1974). However, some forested soils show consistent negative deviations (Riga et al., 1971) and Bremner and Tabatabai (1973) have reported a mean $\partial\ ^{15}N$ value of -0.2 for 16 surface soil samples.

During the summer of 1972, an exploratory study was carried out to determine comparative ^{15}N enrichment of total N and soil nitrates in selected soil profiles. A few preliminary samples were also taken after harvest from field plots which had received up to 300 kg of N/ha at time of seeding. This paper discusses the results of this exploratory survey, and documents the range of ^{15}N abundance obtained on selected soils in the Brown, Dark Brown, and Black Chernozemic zones in the province, and also the Luvisolic-forested soils of the north. Limited information is presented on changes in $\partial\ ^{15}N$ down to depths of 270 cm.

MATERIALS AND METHODS

Soils: A survey of the effect of management practices on sub-soil nitrate levels in selected soils was carried out during the summer of 1972 (Henry, 1974). A number of the samples obtained in this survey were used as source materials for this study. With the exception of profile samples from an irrigated field fertilizer experiment (Table 6 and Figure 3) and a few from land seeded down to tame grass, all samples were from summerfallow fields. The majority of the soils selected, with the exception of those from an irrigated field fertilizer experiment, had never received nitrogen fertilizer.

^{15}N Assay: As soon as possible after the samples were taken, they were dried at room temperature and ground to pass a 2 mm sieve. Analytical and ^{15}N assay procedures used in this study are described in detail elsewhere (Rennie and Paul, 1971). The analyses used for total N, including nitrate and nitrite, is a modified semi-micro version of the method of Bremner (1965). The total N assay involved a pre-treatment of soil samples with acidified permanganate to oxidize nitrite to nitrate, and with reduced iron and sulfuric acid to reduce the nitrate to ammonium. A Kjeldahl digestion is then used to convert all organic nitrogen to the ammonia form. The ammonia evolved by the addition of 40% sodium hydroxide is steam distilled using a quick-fit steam distillation apparatus with 100 ml sample flasks. Cross contamination is avoided by distilling 15 ml of 95% ethanol after each steam distillation to flush the distillation head and condensor.

Nitrate extraction was carried out using a 1:5 soil:water ratio. High speed centrifugation was employed to separate the soil from the solution, followed by filtration through glass fiber filter paper. The extract from 150 g of soil was concentrated using a rotary evaporator to about 25 ml. Conversion of the nitrate N to ammonia was obtained following the procedure of Bremner and Keeney (1966).

The ammonia from either the total N or nitrate N samples was converted to N_2 gas by oxidation with alkaline hyperbromide solution using a Y-tube reaction vessel. The nitrogen-isotope ratio procedure is specifically adapted to an Atlas GD150 mass spectrometer equipped with double inlet and collector system.

<u>Calculations</u>: Kohl et al. (1971) defined $\partial\,^{15}N$ as the per mil enrichment in ^{15}N compared to its enrichment in the air, i.e.

$$\partial\,^{15}N = \frac{\frac{^{15}N}{^{14}N + ^{15}N}\text{(sample)} - \frac{^{15}N}{^{14}N + ^{15}N}\text{(standard)}}{\frac{^{15}N}{^{14}N + ^{15}N}\text{(standard)}} \times 1{,}000$$

Other workers (Riga et al., 1971; Bremner and Tabatabai, 1973; Edwards, 1973) calculated $\partial\,^{15}N$ in the same manner. In contrast, Hauck (1973) defines $\partial\,^{15}N$ not as a function of the % ^{15}N abundance, but as a function of ^{15}N:^{14}N ratios. This is the usual definition that has been followed in carbon-dating research (Campbell et al., 1967). However, because of the comparative simplicity of the gaseous nitrogen species, essentially the same results are obtained and, accordingly, the data reported in this manuscript is calculated from per cent abundance, a more logical and convenient approach.

A measure of the precision of the GD150 mass spectrometer can be estimated from the assay over a one-year period of 66 samples of the ammonium chloride standard; the standard deviation, .0005, indicates that the range of spectrometer error in ^{15}N abundance measurements is less than 2 ∂ ^{15}N units. The reference standard used for all mass spectrometer measurements, reagent ammonium chloride, has a ∂ ^{15}N of 2.03 compared to the N.B.S. atmospheric N standard (.3663 atm % ^{15}N).

RESULTS AND DISCUSSION

The ∂ ^{15}N values obtained for the Chernozemic and Luvisolic Ap horizons show that, on the average, statistically identical levels of enrichment were recorded for the total soil N, and nitrate nitrogen produced under field conditions (Table 1). These data contrast in several ways to that reported in the literature. While the values are of the same magnitude as that reported by Kohl et al. (1971) for nitrate nitrogen derived from a soil sample taken in the vicinity of the Samgamon River Watershed in Illinois, they are very much higher than that of 16 surface soil samples reported by Bremner and Tabatabai (1973). Cheng et al. (1964), Bremner et al. (1966) and Delwiche and Steyn (1970) report a few ∂ ^{15}N values which are equivalent to the values given in Table 1. In general, however, the majority of the samples reported by these authors had ∂ ^{15}N values considerably lower. It is of interest to note that the lowest ∂ ^{15}N values for total N were obtained on soils which had developed under forest vegetation. This is in accord with the trends reported by Riga et al. (1971), but, again, our data contrast quite strongly to that which he reported in that the Belgian forested samples were characterized by ∂ ^{15}N in the negative range.

The ∂ ^{15}N values of the nitrate nitrogen extract corresponded

Table 1. ∂ ^{15}N values for Ap horizon samples of selected soils[a].

Soil	NO_3-N ppm	Total N ppm	∂ ^{15}N values	
			NO_3-N	Total N
Brown Chernozemic				
(Aridic Boroll)				
Sceptre hvc	-	2225	-	8.5
Dark Brown Chernozemic				
(Typic Boroll)				
[d]Sutherland c	23	1990	14.7	11.6
Elstow cl	17	2260	12.1	12.5
Scott l	13	1810	11.3	12.5
[d]Weyburn l	48	3250	0.3	11.7
Asquith fl	17	1370	10.5	11.1
Bradwell sl-1	16	2110	15.8	12.9
Bradwell sl-2[b]	23	1900	13.1	12.4
Black Chernozemic				
(Udic Boroll)				
Oxbow l	19	3120	13.8	11.6
Grey Luvisol				
(Cryboralf)				
Waitville l-1	26	1510	10.0	9.1
[d]Waitville l-2	-	2150	-	6.1
Mean ± Sd[c]			11.3±4.6	11.7±1.1

[a] for further descriptions of the soils, see The System of Soil Classification for Canada (1974). The corresponding 7th approximation terminology is given in brackets.

[b] grass breaking

[c] The total N- ∂ ^{15}N for the Sceptre and Waitville-2 are not included.

[d] Past fertilizer history unknown.

very closely to those obtained from the total N fraction, with one exception, the Weyburn 1 sample; the mean $\partial\ ^{15}N$ value for the nine samples given in Table 1 where comparisons can be made are statistically identical. As expected, however, the standard deviation of the $\partial\ ^{15}N$ nitrate samples is approximately four times as large as that for the total N.

While this study indicates that (for the environmental conditions prevailing in the vicinity of the sampling site) the $\partial\ ^{15}N$ of both total and soil-derived NO_3 is quite similar, numerous authors have shown that the $\partial\ ^{15}N$ of soil-derived nitrate produced on incubation of soils under laboratory conditions is initially very low and frequently negative. Bremner and Tabatabai (1973), for example, report that the ^{15}N enrichment of the nitrate produced in incubation for six weeks was consistently lower than that of the nitrate produced in incubation for 22 weeks--this was not readily evident from the data reported in their report. Delwiche and Steyn (1970), and Edwards (1973) also report $\partial\ ^{15}N$ values for nitrates which are appreciably lower than that for the total soil N. Feigin et al. (1974) report constant values of $\partial\ ^{15}N$ obtained after about 5 weeks incubation which are approximately identical to that for the total N of presumably the same soil (Feigin et al., 1974).

The isotope composition of total soil N in a Brown Chernozemic and Grey Luvisolic profile is given in Table 2. Only slight variations were recorded in the isotopic composition of the total N from the A, B and upper C horizons of the Chernozemic profile; the C horizon was not reached with the depth sampled for the Luvisolic. The ^{15}N abundance was generally greatest at a depth of approximately 45 cm. The distribution of

Table 2. $\partial\ ^{15}N$ and total N for two soil profiles.

Depth* cm	Soil Type		Total N, ppm	
	Chernozemic Brown hvc	Luvisolic Dark Grey l	Chernozemic Brown	Luvisolic Dark Grey
15	8.5	6.1	2220	2150
30	9.1	6.6	1500	1240
45	9.5	8.0	1200	830
60	8.6	8.3	1170	780
75	8.1	7.5	990	620

*0-15, 15-30, etc.

the $\partial\ ^{15}N$ values with depth follow the same trend as that reported by Delwiche and Steyn (1970) for selected yolo fl profile samples.

The third profile recorded in Table 3 was taken to a much greater depth. The significance of the modest decrease in $\partial\ ^{15}N$

Table 3. $\partial\ ^{15}N$ values at various depths.

Depth* cm	Chernozemic Dark Brown c	
	NO_3-N	Total N
15	14.7 (23)†	11.6 (1990)†
120	11.4 (22)	8.1 (640)
150	4.1 (22)	8.5 (670)
180	4.2 (23)	7.6 (351)
240	8.3 (31)	8.4 (540)
270	11.3 (45)	9.2 (440)

*0-15, and 30 cm cores centered on the indicated depth.

†The ppm NO_3-N or total N are given in brackets.

of total N at about the 180 cm depth and the very sharp decrease in ^{15}N abundance for nitrate nitrogen at this depth must await further investigation. As far as is known, the farm field from which the samples were taken has not received any fertilizer nitrogen. The field has traditionally been in a two-year fallow-crop rotation, and substantial quantities of nitrate nitrogen were found both in the rooting zone (85 kg N/ha), and below the rooting zone to a depth of 3.6 m (382 kg N/ha). The majority of this nitrogen has probably been derived from mineralization of soil organic matter.

Contrasting amounts of nitrate nitrogen found at depth in a number of other soils is given in Table 4. The data strongly suggest that management practices which include high frequency of summerfallow or the application of barnyard manure have resulted in the movement and substantial amounts of nitrate nitrogen below the depth of rooting of crops.

The $\partial\ ^{15}N$ values for soil-derived nitrate nitrogen from 21-day incubated and that extracted from field samples for two Chernozemic soils is given in Table 5. Contrary to data reported elsewhere (Delwiche and Steyn, 1970; Bremner and Tabatabai, 1973; Edwards, 1973), the values obtained fro the incubated nitrate nitrogen were only slightly lower than that obtained in the field samples. This obviously reflects two environmental factors, namely that neither soil had received significant amounts of fertilizer N in the past, and also the field samples were taken from summerfallow fields (biological N transformation in quasi-equilibrium).

The similarity between the $\partial\ ^{15}N$ of total soil N and of nitrate N extracted from non-incubated samples from this survey,

Table 4. Rooting zone (0-120 cm) and subsoil NO_3-N levels (Henry, 1972).

Soil and management practices	NO_3-N, kg N/ha	
	0-1.2 m	1.2 m to (m)
Dark Brown Chernozemic		
(Typic Boroll) Sutherland c		
fallow for 10 yrs	206	998 (4.8 m)
2 yr fallow-crop	85	382 (3.6 m)
permanent pasture	8	20 (2.4 m)
Asquith fl		
dryland (2-yr rotation)	11	48 (4.8 m)
irrigated (continuous cropping)	54	169 (4.8 m)
Black Chernozemic		
(Udic Boroll) Indian Head c (rotation experiments established in 1911)		
9-yr rotation (4-yr legume)	61	198 (4.8 m)
3-yr wheat-fallow	32	95 (4.8 m)
3-yr wheat-fallow, plus manure @ 30 t/ha	67	216 (3.0 m)
White Sand sl (in operation 12 yrs with 100 to 200 cattle)		
feedlot	81	49 (3.3 m)
Dark Grey Chernozemic		
(Boralfic Boroll) Shellbrook fl		
Alfalfa	70	30 (4.8 m)
Brome-alfalfa	18	48 (4.8 m)
2-yr rotation	49	51 (4.8 m)
Kamsack sicl		
3-yr rotation	45	52 (4.8 m)
Nipawin l		
grass	12	12 (2.1 m)
3-yr rotation	23	21 (2.1 m)
Carrot River fl		
grass	12	8 (2.1 m)
3-yr rotation	36	15 (2.1 m)

Table 5. $\partial\ ^{15}N$ values for incubated vs field samples of two Dark Brown Chernozemic soils*.

Soil Type	Asquith fl	Elstow cl
Total N	10.5 (1370)	12.5 (2260)
NO_3-N, incubated	9.9 (27)	10.4 (25)
NO_3-N, field sample	11.1 (17)	12.1 (17)

*The incubated samples were leached prior to a 21-day incubation period; the ppm of total or NO_3^- is given in brackets.

with comparison to similar data reported elsewhere, is illustrated in Figure 1. While this figure is self explanatory, it does indicate that the data obtained by Feigin et al. (1974) for samples which had been incubated for 29 weeks and for a number of the samples reported by Bremner and Tabatabai (1973) fall essentially on the same regression line. The figure shows that the $\partial\ ^{15}N$ value of the nitrate nitrogen mineralized under field conditions probably provide a reasonably good estimate of the $\partial\ ^{15}N$ "mineralized nitrogen".

Edwards (1973) concluded that the problem of obtaining a representative soil sample for use in establishing the isotope content of soil-derived nitrate for field investigations is insurmountable, as there is no logical basis for choosing one incubation time over another to reflect the field environment. This observation is supported by the data he reported, and by that of Bremner and Tabatabai (1973). The data reported in this study, however, suggest that the indigenous ^{15}N enrichment of soil-derived nitrate (under field conditions) can indeed be

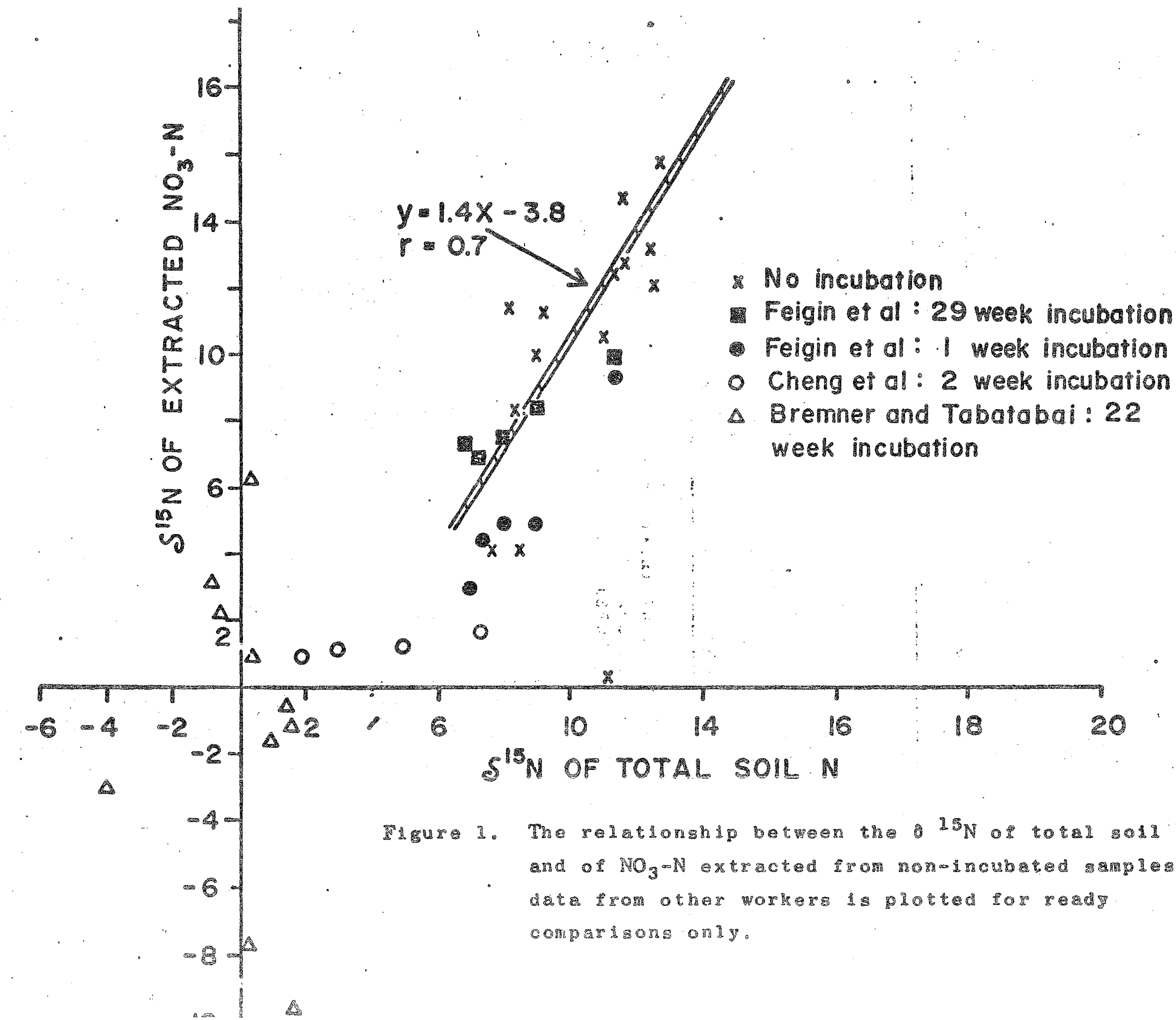

Figure 1. The relationship between the δ ^{15}N of total soil N, and of NO_3-N extracted from non-incubated samples; data from other workers is plotted for ready comparisons only.

established and, further, that the 'readily mineralized soil organic fractions' may not necessarily be characterized by 'low' ^{15}N enrichment levels compared to the more resistant fractions.

There is no adequate explanation for the relatively good correlation between the total N of 19 of the 24 samples included in this survey and the $\partial\ ^{15}N$ of the total soil N. This relationship may be accidental, as it is obvious that five of the soil samples deviate considerably from the calculated regression line. Four of the five points which were excluded from the regression calculations had total N contents considerably in excess of similar samples which had been analyzed previously; there is no plausible explanation for the positioning of the fifth point.

The residual nitrate nitrogen in the 0-120 cm profile of two irrigated field fertilizer experiments is given in Table 6;

Table 6. Residual NO_3-N in the 0-120 cm profile of two irrigated Chernozemic Dark Brown soils following harvest in September, 1972. The data are the mean of six replicates.

Crop	Asquith fl			Elstow cl		
	Fertilizer N application: kg N/ha					
	0	100	300	0	100	300
Wheat	9 (34)†	17 (60)	145* (99)	20 (29)	24 (49)	155 (44)
Barley	6 (25)	14 (76)	73 (138)	18 (25)	21 (57)	76 (91)
Rape	13 (57)	15 (100)	40 (171)	31 (35)	26 (68)	92 (114)
L.S.D. (P=.05)	NS	NS	22	NS	NS	27

*See figure 3 for amount of NO_3-N at depth intervals.

†Plant yield of N, kg/ha is given in brackets.

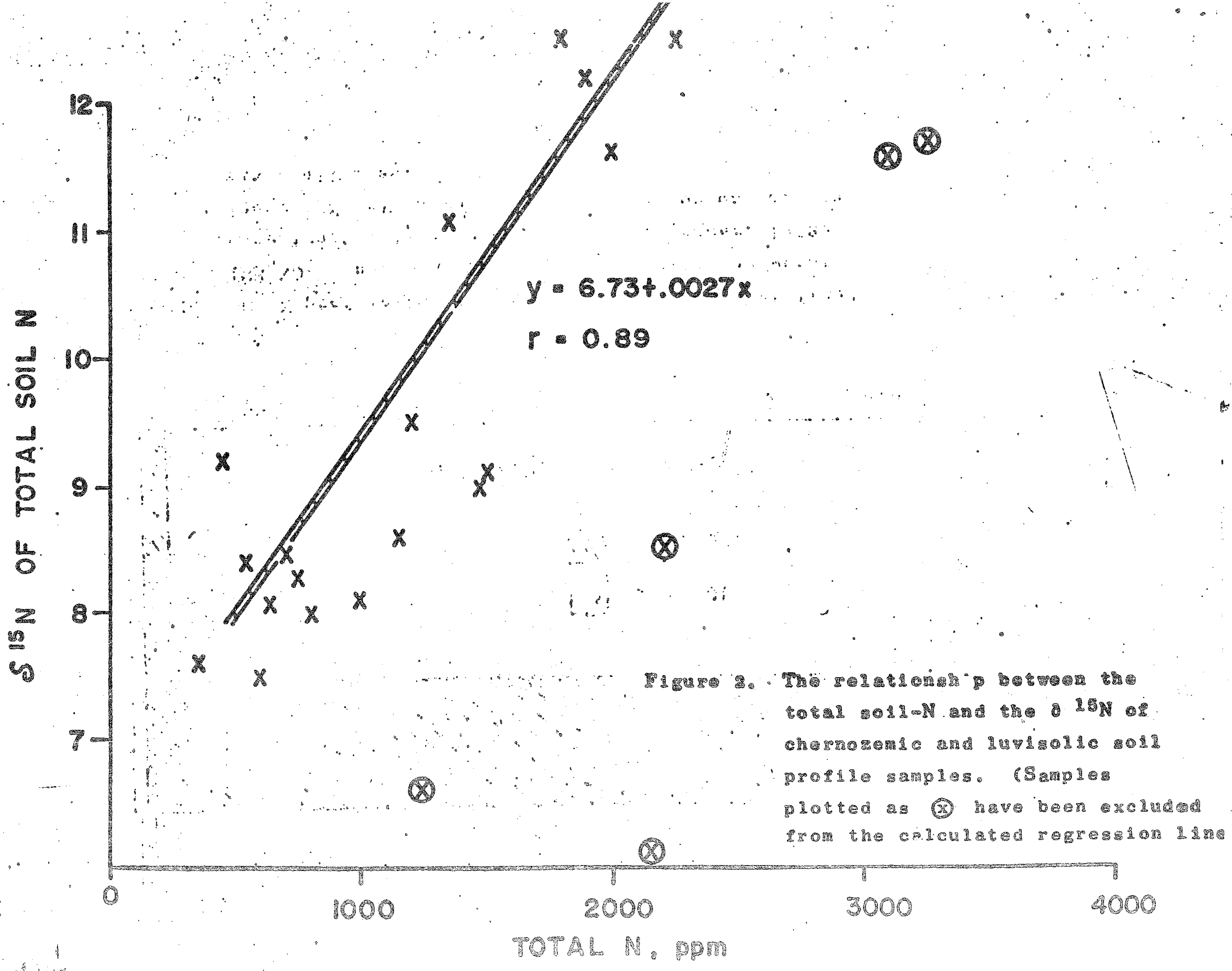

Figure 2. The relationship between the total soil-N and the $\delta\ ^{15}N$ of chernozemic and luvisolic soil profile samples. (Samples plotted as ⓧ have been excluded from the calculated regression line

further detail on specific horizon samples of the wheat plots receiving 0 and 300 kg N/ha of 24-0-0 (see Table 7 for the ∂ ^{15}N value of fertilizer Brand I, which was used in this experiment) is illustrated in Figure 3. Substantial amounts of the 300 kg N/ha rate of application was concentrated in the 30-60 cm depth

Table 7. ∂ ^{15}N values for selected fertilizers.

Brand	Formulation	Compound	^{15}N values*	
			NH_4^-+N	NO_3^--N
1	34-0-0	NH_4NO_3	2.3	6.6
2	21-0-0	$(NH_4)_2SO_4$	7.7	
3	34-0-0	NH_4NO_3	3.9	7.7
		Average	4.6	7.1

*Mean of three determinations. The mean standard deviation of measurement was ± .00031% abundance.

following harvest in 1972. Of interest is the sharp drop in ∂ ^{15}N which characterized the nitrate N in this depth in comparison to that of the 0-30 cm depth. One possible explanation which would require, at the very least, a measure of the ∂ ^{15}N of the plant nitrogen, is as follows: Approximately 250 kg of the 300 applied can be accounted for in the soil and the harvested wheat. A portion of the remaining 50 kg resides in the wheat roots remaining in the soil, while the remainder probably moved below the 120 cm depth. It is very probable that the nitrate nitrogen component of the ammonium nitrate fertilizer used leached more rapidly, and this, together with partial

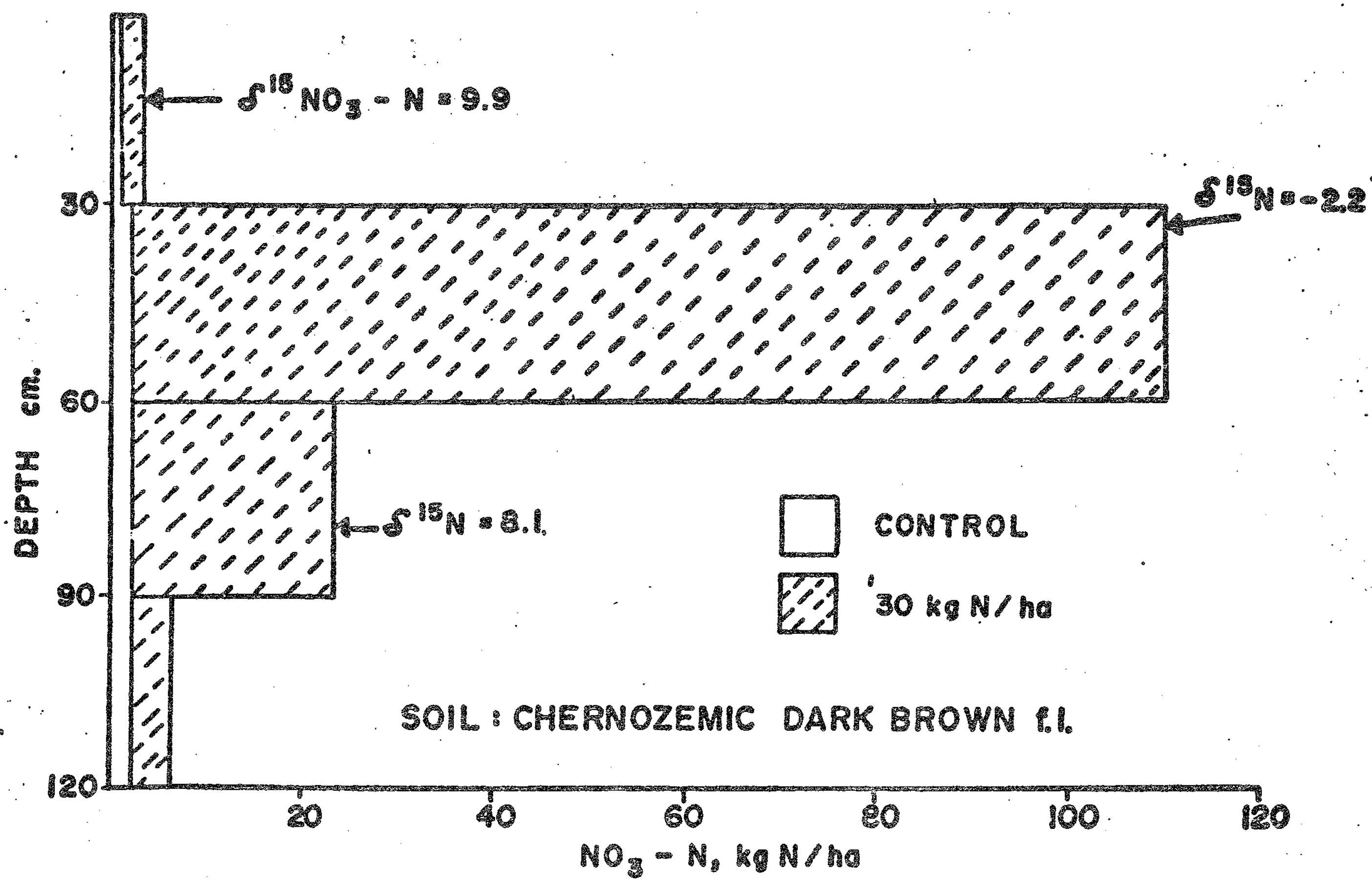

Figure 3. NO_3-N profile (mean of 6 replicates) on fertilized (NH_4NO_3) and control plots of an irrigated wheat experiment following harvest in September, 1972. The δ ^{15}N values were measured only on one of the six replicates.

nitrification of the ammonia nitrogen would tend to decrease the $\partial\ ^{15}N$ of the nitrate at lower depth in the soil. The majority of the enriched nitrate nitrogen mineralized from the ammonia source at a somewhat later time was probably taken up by the plants. While this explanation is speculative, to say the least, it does indicate a potential application of changes in the natural isotope abundance which are not possible when enriched materials are used.

CONCLUSIONS

The following main observations can be drawn from the preliminary survey of $\partial\ ^{15}N$ values for the limited number of soil samples included in this study.

1) The $\partial\ ^{15}N$ for total soil N ranged from a low of 6.1 to 12.9 with the Chernozemic soils characterized by relatively high, and the Luvisolic low values. The $\partial\ ^{15}N$ values for nitrate N derived under field conditions was, in general, similar to that for the total N.
2) The $\partial\ ^{15}N$ for soil horizon samples reached a maximum for the 30-45 and 45-60 cm depth for a Chernozemic Brown and Luvisolic Dark Grey profile, respectively.
3) The $\partial\ ^{15}N$ of the total and nitrate nitrogen of samples taken to a depth of 270 cm from a Chernozemic Dark Brown clay soil reached minimum values at about the 180 cm depth; $\partial\ ^{15}N$ for the nitrate samples taken at this depth were approximately 1/3 of those found in the surface horizon.
4) The $\partial\ ^{15}N$ of nitrate derived N from a 21-day incubated sample and field samples were essentially the same, and very close to that for the total N.

5) A relatively good correlation was obtained between the total N content of soils and the $\partial\ ^{15}N$ of the total soil N.

6) The NO_3-N of subsurface soil horizons containing residual fertilizer N had very low $\partial\ ^{15}N$ values (-2.2) compared to the surface horizon (9.9).

The data obtained from this preliminary survey suggest that the natural variations in ^{15}N abundance between different soils, and horizons of the same soil probably reflect the cumulative effects of soil genesis and soil management. More detailed knowledge and understanding of biological and other processes which control N-isotope concentrations in these soils must be obtained before the data reported can be adequately interpreted.

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